Essays on the theory of collusion

Overvest, Bastiaan Marinus

Essays on the Theory of Collusion

Bastiaan Marinus Overvest

Publisher: PrintPartners Ipskamp
P.O. Box 333
7500 AH Enschede
The Netherlands
Tel: +31 (0)53-4826262

ISBN: 978-90-367-3942-9

This document was prepared using LaTeX.

RIJKSUNIVERSITEIT GRONINGEN

Essays on the Theory of Collusion

Proefschrift

ter verkrijging van het doctoraat in de
Economie en Bedrijfskunde
aan de Rijksuniversiteit Groningen
op gezag van de
Rector Magnificus, dr. F. Zwarts,
in het openbaar te verdedigen op
donderdag 24 september 2009
om 14.45 uur

door

Bastiaan Marinus Overvest

geboren op 24 februari 1980
te Leeuwarden

Promotor:	Prof. dr. J.L. Moraga-González
Copromotor:	Dr. M.A. Haan
Beoordelingscommissie:	Prof. dr. H.W.A. Dietzenbacher
	Prof. dr. M.C.W. Janssen
	Prof. dr. E.G. Wolfstetter

Acknowledgments

This thesis has benefited greatly from the help and encouragement of many people. Above all, I would like to thank Ben Heijdra, Jakob de Haan and Peter Kooreman for showing me the scope and beauty of economics when I was still an undergraduate student. Without their stimulating courses this thesis possibly would not have existed.

Marco Haan and José Luis Moraga-González have provided me with invaluable guidance. Like many others (see the acknowledgments in Heijnen (2006) and the references cited therein), I have experienced Marco's accessible style as very helpful. He was and is always willing to discuss new ideas. I am grateful that José Luis was willing to act as my promotor. His advice helped to sharpen my papers considerably and, perhaps even most importantly, he showed by example how good research should be done.

Various other people have helped to shape my ideas. Among these are Olivier Bos, Giacomo Calzolari, Lammertjan Dam, Robert Dur, Martijn Han, Pim Heijnen, Allard van der Made, Jan Potters, Régis Renault, Bert Schoonbeek, Maarten-Pieter Schinkel, Roland Strausz, Joël van der Weele and Frans van Winden.

A special thanks must go to Jenny Ligthart of NAKE. Her organization enables young PhD's to attend lectures of internationally renowned economists. At the NAKE workshops, Ivy League professors have shown me how fascinating good research can be.

I will remember my years in Groningen as an inspiring, intellectual and overall very enjoyable time. Not in the least, this is because of the many coffee breaks I had with Allard, Lammertjan, Marco, Linda, Pim and Remco during which we discussed our slightly less scientific ideas.

Outside academia, I could rely on many friends for comfort, support and diversion. The most important person I need to thank here is Agnes. She is by far my best friend and knows me better than anyone else. I am looking forward to spending my life with her.

Contents

Chapter 1

Introduction

> No one has the right, and few the ability, to lure economists into reading another article on oligopoly theory without some advance indication of its alleged contribution.
>
> George J. Stigler (1964, p. 44)

1.1 Motivation

Voluntary cooperation between independent actors typically promotes social welfare. Collusion, which can be defined as the overt or tacit coordination between firms on one or more strategic variables such as price or advertising, is an important exception to this principle. When two or more firms coordinate on a high price, they may increase their joint profits, but typically ignore the negative externality they impose on consumers. As a result, collusion between firms has, in general, a negative impact on social welfare (Whinston, 2006). This is why collusive agreements are subject to legal prosecution in the United States, member states of the European Union, Canada, and many other countries.

Many important aspects of collusion are still poorly understood. The aim of this thesis is to shed light on a few of those aspects. Using existing game-theoretic models when possible and proposing new frameworks when necessary, the chapters in this thesis contribute to a better understanding of cartels. Each chapter is intended to appeal to both academics and economists at antitrust authorities or in policy circles.

The thesis is split into two parts. Each essay in Part I considers the impact of a particular real-world disturbance on collusion. Actual cartels do not operate in a sterile and solitary space, but interact with various other agents on the market. External parties such as the antitrust authority, potential entrants or upstream firms continuously aim to affect the cartel. Part II is devoted to the analysis of collusion in auctions. An auction is a special type of market, in which many of the imperfections that are common in many other markets are 'designed away'. This allows for a clean analysis of the scope for collusion.

The first chapter introduces a conflict between an incumbent cartel and potential entrants. New firms may join the cartel, but possibly have a destabilizing effect on collusion. Entry deterrence, for instance by lobbying the government, is feasible but costly. The model features equilibria with finite cartel duration. The analysis could therefore help to explain why some cartels are active for a much longer period than others.

A key task of antitrust authorities, such as the Antitrust Division of the U.S. Department of Justice or the German Bundeskartellamt, is to enforce antitrust legislation by searching for cartels and appropriately penalizing them. A formal model of the interaction between the antitrust authority and firms can reveal whether and how the institutional structure can be adjusted to decrease the incidence of collusion. Chapter 3 deals with this challenge.

The typical industrial organization model supposes that, if firms form a cartel, they coordinate on all strategic variables. In practice, coordination is imperfect. According to Symeonidis (2002), most cartels fix prices, but still compete on other dimensions, such as quality. What are the consequences of this form of imperfect coordination for consumers, firms, and antitrust authorities? Chapter 4 investigates this issue.

Chapter 5 takes up a classic theme in industrial organization theory: resale price maintenance. A popular view, articulated by policymakers and theorists, is that resale price maintenance helps firms to form a cartel. Nevertheless, the U.S. Supreme Court recently lifted the ban on this type of vertical restraint and an obvious question is whether the European Union should copy this move.

The first chapter of Part II presents a survey of the literature on collusion in auctions. This form of collusion, also known as bid rigging, has received quite some attention from industrial organization economists. The knowledge contained in this literature is highly relevant, given the fact that an increasing number of transactions are nowadays settled through auctions. Unfortunately, this literature is rather dispersed and, due to the mathematical nature of many key contributions, inaccessible to many laymen.

There are, still, some open questions about bid rigging. Public procurement is often conducted by means of multidimensional auctions. In multidimensional auctions a bidder's offer consists of at least two elements, most often a price and an index of quality. Given that public procurement is plagued by cartels, it would be helpful to understand how collusion works in multidimensional settings and how to deter it.

Economists often marvel at the efficiency and simplicity of auctions to allocate resources. However, many desirable properties of auctions vanish as bidders start to collude. This raises the question whether other allocation mechanisms, such as negotiations, are to be preferred in collusive environments.

The remaining part of this introduction substantiates on the general approach (section 1.2) and offers a detailed preview of the subsequent chapters (section 1.3).

1.2 Methods and main themes

1.2.1 Collusion as a research topic

As the reader will quickly notice, many chapters in this thesis start with a quotation from a distinct antitrust economist. Five chapters cite Nobelist George Stigler and one chapter (5) vouches Lester Telser. Both scholars are renowned exponents of the famed (and infamous?) Chicago school of economics. The use of their words is not intended to conceal a distress of original ideas or to convey a sectarian adherence to a blunt free market ideology. Instead, the use of Telser and Stigler's lines is meant to honor the contribution of the Chicago school to industrial organization. An important methodological contribution of the Chicago school is the insistence on concepts such as rational consumers and profit maximizing firms. Those concepts are nowadays considered as standard assumptions.

According to Posner (1979), early members of the Chicago school probably did not consider collusion as a serious problem. Since Adam Smith ("People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.")[1], the incentive of firms to coordinate was well understood, but Chicagoans considered it unlikely that firms can successfully cooperate, as any cartel member has a destabilizing incentive to undercut the collusive price and supra-competitive profits attract new firms. And even if firm are able to form a stable cartel, their

[1] Smith (1776), book I, chapter 10.

economic impact was deemed to be small, according to Harberger's (1954) modest estimate of the deadweight loss of monopoly. Stigler brought the subject of collusion back to the main stage. In his seminal article *A theory of oligopoly*, he introduced the idea of tacit, instead of explicit, cooperation and approached collusion as any other economic activity. Firms are expected to collude whenever the (long-run) benefits exceed the (long-run) costs.

Simple cost-benefit analysis also forms the basis of much of this thesis. Cartel members deter entry by new firms only if it is in their self-interest. Antitrust agencies investigate suspicious prices only if they have an incentive to do so.

1.2.2 Approach

This thesis does not pretend to form a full-blown comprehensive theory of collusion, but merely tries to contribute to the literature by focusing on a few selected topics. Consult Feuerstein (2005) for a recent survey of the economics of collusion.

The general method in this thesis is to construct theoretical models of firm interaction and study the equilibrium properties. This approach has a long tradition in the industrial organization literature and is still the dominant theoretical framework. There are various reasons for relying on theory instead of a more empirical approach.

The first reason is that many important questions (*e.g.* what is the effect of semicollusion on quality?, what is the effect of resale price maintenance on the scope for collusion?) are difficult to answer empirically, because they require the use of control groups or proper instruments to identify the effect the researcher is interested in. It is practically impossible to set up two antitrust authorities with different objective functions to determine the optimal objective for antitrust policy, for instance. Theoretical models allow the economist to conduct a small-scale thought experiment. These experiments are useful because the results guide policymakers at low costs. For instance, a government procurement agency can independently experiment with various procurement procedures, but it seems more efficient to first seek advice from theoretical models. A second reason for theorizing is that important phenomena may not be directly observable and, as a result, are plagued by a lack of data for empirical research. As an example, chapter 2 models cartel duration, which is typically an unobservable variable. The first step to understand such unobservable processes is to develop a consistent theory. After that, the theory may be used to derive empirical implications. This relates to the third reason for theory, which is that theoretical insights help empirical economists by informing them what to look for in the data.

1.3 Outline of the thesis

1.3.1 Part I

The traditional Chicago view holds that collusion is likely to break down when new firms are free to enter the market. This sounds reasonable, but ignores that in reality cartels do exist for some period, and that incumbents have an incentive to prevent entry by various means. A cartel may deter entry by legitimate means, such as an industry-wide advertising campaign, or illegitimate means, such as threats of violence. An expressive example of such unlawful strategies comes from the New York garbage hauling sector, in which an entrant received the severed head of a dog. The accompanying note said "Welcome to New York". (*The Economist*, March 12, 1994, pp. 33–34).

A more conventional entry-deterrence strategy is to lobby the government. Cartel members may protect their cartel by pressing for stricter regulation, high import tariffs, or a permit system. This behavior is typically legal in many countries. In the United States, for instance, the Noerr-Pennington doctrine states that it cannot be a violation of antitrust laws to lobby to change the law in a way that would reduce competition.[2]

To study the interplay between collusion and entry, chapter **2** introduces a model in which incumbents may lobby the government to deter entry. In each period, entry is perfectly deterred if at least one incumbent invests a fixed amount in an entry deterrence technology. Assuming that cartel members do not coordinate their lobbying activity, the model yields finite cartel duration in the symmetric equilibrium. Each firm deters entry with positive probability. It is possible to derive a closed-form expression for cartel duration and testable predictions of its determinants. When demand is subject to unobservable shocks, a cartel is more likely to collapse during price wars than during a collusive phase.

These results reconcile the Chicago view of collusion with the standard 'folk theorem' interpretation of collusion. Even when entry occurs with certainty, collusion can still be a stable equilibrium. Finite cartel duration is also a novel result. Conventional models of collusion predict that cartels are either stable, and last forever, or are unstable, and fail to emerge at all. Therefore, the model may help to

[2] This doctrine is based on two antitrust cases, *Eastern Railroad Presidents Conference* v. *Noerr Motor Freight, Inc.*, 365 U.S. 127 (1961) and *United Mine Workers* v. *Pennington*, 381 U.S. 657 (1965).

explain actual cartel duration. This can be valuable to antitrust authorities, as the predictions of the model help to determine which cartel is likely to be most stable.

In practice, the task of enforcing antitrust laws is delegated to a specialized antitrust agency. With respect to collusion, the goal of an antitrust agency is, or should be, to deter collusive practices by detecting cartels and impose monetary sanctions, or even prison sentences, if a firm is found guilty. The interaction between antitrust agencies and firms has been studied in considerable detail in the industrial organization theory literature. Besanko and Spulber (1989) is exemplary for this literature. The aim of Besanko and Spulber (1989) is to derive an optimal strategy for the antitrust authority that maximizes social welfare. The critical assumption is that the antitrust authority commits to this strategy. Thus, the focus of this literature can be classified as normative.

Chapter **3** offers a positive analysis of the strategic interaction between the antitrust agency and cartels. In line with the fundamentals of price theory, the chapter proposes a model in which the antitrust authority is rational. It decides to investigate an industry if and only if it believes that the expected payoff outweighs the costs. Moreover, the antitrust authority is willing to impose a fine if and only if it is optimal to do it, *ex post*.

The assumption that the antitrust authority behaves opportunistically carries a substantial degree of realism. The recent Dutch experience in the settlement of the large-scale construction cartel suggests that antitrust authorities refrain from imposing high fines.[3] Stephan (2006) forcefully argues that, in general, antitrust authorities suffer from 'weak knees' in deterring collusion and provides several additional examples.

It is found that collusion cannot be deterred perfectly. Firms still collude with some probability, even if the antitrust authority is given strong incentives to investigate suspiciously high prices. The government can induce the antitrust authority to adopt a tougher anti-cartel stance by adjusting the antitrust authority's objective function. This result may explain why antitrust authorities often seem to maximize consumer welfare.

When firms decide to form a cartel, it seems to be optimal, at least in theory, to collude on *all* strategic variables, such as price, quality and advertising. A remarkable feature of real-world cartels, however, is that they seem to collude on

[3] See for instance "Bouwbond vreest banenverlies na recordboete NMa" (Construction union fears loss of jobs after record-high fines Dutch antitrust authority), *Het Financieele Dagblad*, January 6, 2004 and "NMa verlaagt boetes voor bouwfraude; Risico van 'omvallen' hele bedrijfstak" (Dutch antitrust authority lowers fines construction cartel; Risk of collapse entire industry), *NRC Handelsblad*, October 15, 2004.

only a subset of strategic variables (Symeonidis, 2002). This behavior is known as semicollusion. In particular, firms tend to fix prices in collusive negotiations, but subsequently compete against each other by providing service. The analysis in Chapter **4** takes this behavior as given and explores the consequences on prices, quality, profits and consumer welfare.

The main question in this chapter is whether semicollusion nullifies the adverse effect of high collusive prices on consumer welfare by increasing the level of services. The chapter develops a model in which firms have two strategic variables, price and quality. The model is based on recent theoretical papers by Anderson and Renault (1999) and Wolinsky (2005). It is found that the ability to compete on one dimension constrains firms to obtain fully collusive profits. The semicollusive price is set below the monopoly price to prevent firms to compete the collusive profits away by offering excess quality and may even be lower than the non-cooperative price. As a result, a detection strategy based on investigating 'suspiciously' high prices may expose only non-cooperative behavior.

Chapter **5** considers the impact of vertical restraints on collusion. Vertical restraints, such as price floors or exclusive territories, are subject of much controversy. The traditional Chicago position can broadly be characterized as stressing the efficiency effects of vertical restraints. A franchise system (or a two-part tariff), for instance, allows an upstream firm to solve the so-called double marginalization problem. This specific vertical restraint generally increases social welfare and, most importantly, increases the upstream firm's profits. Other economists emphasize the potential pro-collusive effects of vertical restraints. As a specific example, a price floor might enable downstream firms to form a stable cartel. The problem with this example is that an upstream has no incentive to assist the downstream firms in forming a cartel, as his profits decrease when the downstream firms increase their price-cost margin.

The legal stance toward vertical restraints is, in general, dismissive of price constraints, but much more lenient toward non-price restraints such as exclusive dealing or tie-ins. This seems reasonable. After all, a price floor, which is a common type of vertical restraint, hinders downstream firms to compete by charging lower prices.

This chapter reexamines this reasoning. The analysis produces a surprising insight. It is rational for a manufacturer to impose a price floor, not because this fosters downstream collusion, but because this induces non-cooperative behavior. A high price floor is shown to have a destabilizing effect on cartels. This is a notable result, because it provides an additional argument in favor of the efficiency view of vertical restraints and destroys an important part of the justification of the *per se* illegality rules of price floors.

1.3.2 Part II

In many countries, the government regularly procures goods and services by means of auctions. The amounts involved in these procurement auctions are substantial. One estimate holds that the value of goods and services purchased via auctions sums to 16% of the European Union's GDP.[4] Auctions are a fast, transpararent and often efficient method to allocate contracts. Unfortunately, auctions are also particularly sensitive to collusion.

The typical procurement auction (*e.g.* for the construction of a hospital) has many features that makes it particularly susceptible to collusion. The procurement agency has unit demand (the hospital) and its maximum willingness to pay (the agency's budget) is often publicly announced. These conditions imply that the demand function is known with certainty and eases the firms' ability to determine a collusive price. Furthermore, the auction rules often stipulate that the contract is to be awarded to the firm which announced the lowest price. This rule seems to be pro-collusive as it makes it more difficult for a firm to deviate from a cartel's agreement. A firm that charges below the price of the cartel's designated winner is immediately caught by its fellow conspirators.

These and many other properties make auctions the ideal environment for collusion. Accordingly, a vast majority of antitrust violations occurred in auctions (Froeb, 1988). Not surprisingly, the auction theory literature devoted much attention to the possibility of collusion in auctions over the last twenty years. Chapter **6** summarizes this literature. The aim of this chapter is to inform auction theorists of the current insights and to help policymakers to design auctions that are less vulnerable to collusion.

Public procurement auctions typically have price and quality aspects. To understand collusion in these settings, chapter **7** characterizes optimal collusive mechanisms for two-dimensional procurement auctions. The government, which is ultimately the buyer in public procurement, can lower the costs of collusion by using a reservation utility auction. This auction is the natural extension of a one-dimensional auction with a reserve price and may even deter collusion in some cases.

[4] See http://europa.eu.int/comm/internal_market/publicprocurement/index_en.htm.

Auctions are not the only method to procure goods and services. A popular method is to simply negotiate the terms of the contract with a single firm. However, standard auction theory (see Binmore and Klemperer, 1996) shows that auctions are likely to result in considerably lower prices than negotiations. An important question is therefore why negotiations are still widely used. The analysis in chapter **8** establishes that negotiations are optimal when the buyer faces a cartel. An auction with an all-inclusive cartel results in a zero surplus for the buyer. Negotiations, on the other hand, with a single cartel member allow the buyer to extract some of the cartel profits.

The final chapter offers a general conclusion. It elaborates on the main implications for antitrust policy and discusses various avenues for future research.

Part I

Collusion on markets

Chapter 2

Entry deterrence, coordination, and finite cartel duration

> Every industry or occupation that has enough political power to utilize the state will seek to control entry.
>
> George J. Stigler (1971, p. 5)

2.1 Introduction

Why do some cartels last longer than others? This question is rarely asked in industrial organization. It is unclear why the quest for understanding the determinants of cartel duration has not received more attention in the literature. For instance, evaluating current antitrust policy requires a proper understanding of the welfare costs of collusive conduct. An important determinant of these welfare costs is the duration, or longevity, of a cartel.

There is little theory to guide the policymaker or applied economist. Conventional models of collusive behavior predict that cartels are either stable, and last forever, or are unstable, and fail to emerge at all. This prediction is at odds with cartel duration data, which shows that cartels are often short-lived. This chapter proposes a model that explains finite cartel duration.

Clearly, the mere observation of an episode of high price-cost margins followed by an episode of low price-cost margins is not sufficient to establish that cartels have finite lifetimes. In some models of collusion price wars may occur in equilibrium. This suggests that it is *a priori* impossible to distinguish between a price war and a cartel breakdown. However, Levenstein and Suslow (2006) write that "[o]ur overview of the empirical literature suggests [that] the outbreak of a price war–as opposed to the threat of a price war–is rarely a sign of cartel success [and] cartels break down in some cases because of cheating, but more frequently because of entry, exogenous shocks, and dynamic changes in the industry." These empirical observations suggest that it is safe to assume to cartel breakdowns are more common than equilibrium price wars.

The central idea of the model is that the threat of entry entails a coordination problem that may lead to the cartel's demise. Incumbent firms may form a cartel and increase their current profits. Every period they face the threat of entry of potential firms. If the incumbents do not take actions to deter entry, the new firms enter the market and firm profits decrease. Entry can be deterred by investing in a general entry deterrence technology. One interpretation of this technology could be lobbying the government to legally restrict entry. Entry deterrence is an indivisible public good: if at least one incumbent incurs the fixed cost of deterring entry, all other incumbents benefit. If the cartel is unable to coordinate on entry deterrence, incumbents act non-cooperatively when deciding whether to deter entry. In the symmetric Nash equilibrium, incumbents deter entry with some probability. This results in an endogenous probability that the cartel breaks down. Though the model is simple, it yields novel and sometimes counterintuitive insights about the determinants of cartel duration. The model's predictions may be valuable in empirical studies of cartel duration.

This chapter advances coordination failures as the key determinant of finite cartel duration. However, the are some alternative explanations. A typical interpretation of cartel breakdowns is that collusion ended because a firm cheated by undercutting the cartel price. This explanation cannot be correct, or at least rational, because firms know that cheating will be met by an episode of fierce competition, and this deterrent effect of the punishment phase ensures that collusion is a stable equilibrium. Another possible explanation is that cartels are unstable because antitrust authorities have adopted leniency policies. This argument ignores that even cartels that are perfectly legal may be unstable. For instance, in his analysis of the Webb-Pomerene export cartels that were granted exemption of the Sherman act, Dick (1996) reports that the average cartel duration was between 5 and 6 years.

The outline of the remainder of this chapter is as follows. The next section discusses the related literature. Section 2.3 introduces the formal model. The main results can be found in section 2.4 and the empirical implications are discussed in section 2.5. The model can be easily adjusted to allow for more general environments, as shown in Section 2.6. Introducing demand shocks, for instance, implies that the equilibrium features both temporary price wars and finite cartel duration. Brief conclusions can be found in section 2.7.

2.2 Related literature

Just two papers propose a formal theory of cartel duration, Jacquemin, Nambu and Dewez (1981) and Harrington (2007). Jacquemin *et al.* deviate from the standard equilibrium requirement of collusion, by *assuming* that a cartel is stable, in the sense that cartel members never cheat. Every period that a cartel is active, it incurs an organization and maintenance cost. This cost is assumed to depend on standard factors such as the industry's concentration or the degree of homogeneity of the product, but also on less conventional and problematic ones, such as 'the degree of encouragement by the public authority'. Moreover, the cost and benefits are time-dependent. Cartels therefore face a problem of finding the optimal cartel length that maximizes the joint profits. Thus, the problem of cartel duration is reduced to a simple cost-benefit analysis. Jacquemin *et al.* (1981)'s model is to a large extent *ad hoc*, because the problem of cartel stability is ignored and the inclusion of the various factors is merely driven by data availability than by theoretical considerations.

Harrington (2007) is perhaps closest related to the analysis in this chapter, as he requires that collusion is an equilibrium phenomenon. He studies birth and death processes for cartels to understand the proportion of cartels. Firms have an opportunity to form a cartel at irregular intervals. The cartel breaks down with some probability as demand shocks induce firms to defect from the cartel agreement. The main differences between Harrington's model and the one in this chapter are that Harrington treats cartel dissolution as exogenous and ignores entry.

The essential ingredient in this chapter's model is entry deterrence. This is extensively studied in the literature. Dixit (1980) shows that installing capacity enables an incumbent monopolist to credibly deter entry of a potential firm. When there are multiple incumbents, entry deterrence is a public good and a coordination problem may arise. See Gilbert and Vives (1986), Waldman (1987), Appelbaum and Weber (1992) or Kovenock and Roy (2005) for models that feature this idea.

Despite the large literature on entry deterrence, it is rarely discussed in connection with collusion. For example, in his survey about the strategic analysis of entry deterrence, Wilson (1992) does not mention collusion at all. Hence, an additional contribution of this chapter is the introduction of collusive behavior in a dynamic model of entry deterrence.

2.3 A model of dynamic entry deterrence

There are $n \geq 2$ incumbents and $k \geq 1$ potential firms, who may enter the market if entry costs are sufficiently low. Every period $t = 0, 1, 2, \ldots$, the firms play a simple two-stage game. In the first stage, the entry deterrence stage, each incumbent firm may invest a fixed amount $K > 0$ in erecting an entry barrier. The entry costs c for each potential firm are

$$c = \begin{cases} 0 & \text{if none of the incumbents invested} \\ +\infty & \text{if at least one incumbents invested.} \end{cases} \tag{2.1}$$

It is clear that this is a very strong assumption about the entry deterrence technology.[1] The main reason for imposing this particular form is to keep the model tractable. Moreover, this technology restricts the incumbents' investments to have a purely entry deterrent effect and therefore helps to clarify how coordination failures lead to finite cartel duration. The entry deterrence technology can be interpreted as a reduced form of a lobbying game: at cost K, the government is willing to impose legal entry barriers.[2] This is not entirely unrealistic. According to Levenstein and Suslow (2006) "cartels have turned to the state to create regulation (e.g., salt), impose export tariffs (potash), or provide anti-dumping protection (citric acid) with the goal of excluding outsiders" (p.74).

The crucial assumption of the model is that incumbents are unable to coordinate on deterrence. One argument for this assumption starts by noting that an effective lobby is a coherent and well-organized effort to influence the policymaker. Splitting the lobbying activity into several distinct small lobbies creates confusion and makes it increasingly likely that the policymaker is not convinced. Given this indivisibility, it is attractive for incumbents to quit a joint lobby attempt when at least one incumbent still continues to lobby. Moreover, this incentive to free-ride on a single incumbent's efforts may be even stronger because the need to deter entry

[1] Section 2.6.2 considers a more general specification and shows that the main results are unaffected.

[2] Other interpretations are equally valid. The firms could invest K in advertisements or R&D to keep potential firms at a lag. Or K can be thought of the 'maintenance cost' of a cartel.

is likely to arise infrequently. Then, the incumbents perceive the entry deterrence game as a one-shot game.

In the second stage, the market stage, the potential firms observe the actions of the incumbents and may enter the market. At the end of the second stage, profits are realized. Figure 2.1 summarizes the sequence of events in the stage game.

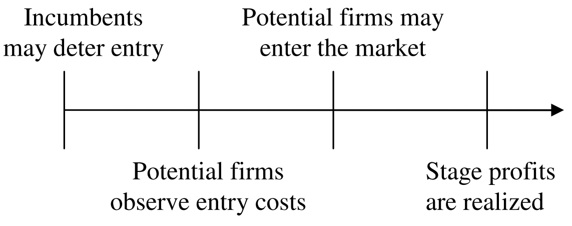


Figure 2.1. Timing of the stage game.

The exact nature of competition and behavior at the second stage is left implicit. The firms could be playing a Cournot or a Bertrand game, and they may be acting cooperatively or non-cooperatively. If m firms are active, each active firm receives $\pi^I(m) \geq 0$, where I is the mode of behavior. This chapter considers three possible types of behavior of firms; non-cooperative behavior (N), collusive behavior (C), and optimal deviation by a single firm from a cartel agreement (D). As is standard, it is assumed that $\pi^D(m) > \pi^C(m) > \pi^N(m)$. Consistent with many industrial organization models, it is supposed that $\pi^I(m)$ is decreasing in m and $\lim_{m\to\infty} \pi^I(m) = 0$ for $I \in \{N, C\}$.

The assumption that $\lim_{m\to\infty} \pi^I(m) = 0$ is made to simplify the analysis. Without it, the potential firms may face a coordination problem that complicates the derivation of the equilibrium. In the absence of fixed costs, each potential firm enters the market and the incumbents' profits drop from $\pi^I(n)$ to $\pi^J(n+k)$. Note that the mode of behavior may change, because the current collusive agreement may not be stable for the new number of firms.

The stage game is infinitely repeated. Each firm discounts the payoffs obtained at period t with a discount factor $\beta \in (0, 1)$. The payoffs within stage games are not discounted.

All aspects of the model are common knowledge. Each firm is risk-neutral and aims to maximize expected profits. Since firms are symmetric and the game is stationary, it is natural to focus on symmetric stationary equilibria. It will be helpful to introduce some additional notation to derive the equilibrium. Let $V^I(\boldsymbol{\lambda})$ be the *value*, or the discounted expected sum of future profits, of an incumbent firm when all firms deter entry with probability λ and the mode of behavior is I. Furthermore, let $V^I(\lambda_i; \boldsymbol{\lambda}_{-i})$ be the value of an incumbent i which deters entry with probability λ_i when all other incumbents deter entry with probability λ.

2.4 Results

2.4.1 Equilibrium entry deterrence

To find the equilibrium, suppose first that the incumbent firms currently earn π^I at each stage game, where $I \in \{N, C\}$.[3] That is, the firms either act non-cooperatively or cooperatively. It is easy to see that if $\pi^I - K > \pi^J$, there cannot be an equilibrium in which no incumbent deters entry. Recall that π^J denotes the stage profits of each firm after entry, where $J \in \{N, C\}$. If entry is not deterred, new firms enter the industry and stage profits become π^J. An incumbent can profitably deviate from this proposed equilibrium by incurring a cost K every stage game. This yields a value of

$$\begin{aligned} V^I(\lambda_i = 1; \boldsymbol{\lambda}_{-i} = \mathbf{0}) &= \sum_{t=0}^{\infty} \beta^t (\pi^I - K) \\ &= \frac{\pi^I - K}{1 - \beta}. \end{aligned} \tag{2.2}$$

Now, consider an equilibrium in which all incumbents deter entry. Then, the value of each incumbent is

$$V^I(\boldsymbol{\lambda} = \mathbf{1}) = \frac{\pi^I - K}{1 - \beta}.$$

It is rational for an individual incumbent i to deviate from this proposed equilibrium. Not deterring entry (setting $\lambda = 0$) increases its value to

$$V^I(\lambda_i = 0; \boldsymbol{\lambda}_{-i} = \mathbf{1}) = \frac{\pi^I}{1 - \beta}.$$

These observations imply that for $\pi^I - K > \pi^J$ the remaining candidate symmetric equilibrium must be in mixed strategies. Given that the potential firms have not entered the market, each incumbent deters entry in the stage game with some probability $\lambda \in (0, 1)$. (It is clearly a dominated action to deter entry after the potential firms have entered.) In a mixed strategy equilibrium, each incumbent firm must be

[3] The argument of $\pi(\cdot)$ is dropped when confusion is unlikely.

indifferent between deterring entry and not deterring entry. This means that

$$V^I(\lambda_i = 0; \boldsymbol{\lambda}_{-i}) = V^I(\lambda_i = 1; \boldsymbol{\lambda}_{-i}) \tag{2.3}$$

holds in each period before entry. Given that each firm chooses to deter entry with probability λ, this equilibrium condition can be written as

$$(1-(1-\lambda)^{n-1})(\pi^I + \beta V) + (1-\lambda)^{n-1}\frac{\pi^J}{1-\beta} = \pi^I - K + \beta V, \tag{2.4}$$

where V is the equilibrium value of $V^I(\boldsymbol{\lambda} = \mathbf{0})$ and $V^I(\boldsymbol{\lambda} = \mathbf{1})$. An incumbent who chooses not to deter entry obtains a profit $\pi^I + \beta V$ if at least one of the other incumbents deters entry, and a profit π^J if entry occurs. These events occur with probability $1-(1-\lambda)^{n-1}$ and $(1-\lambda)^{n-1}$, respectively. In a mixed strategy equilibrium, this expected profit equals the profit obtained by deterring entry with certainty. Furthermore, the value of an incumbent who chooses either action must be V.

It is straightforward to solve equation (2.2) for the equilibrium entry deterrence probability λ^*:

$$\lambda^* = 1 - \left(\frac{K - \beta K}{\pi^I - \pi^J - \beta K}\right)^{\frac{1}{n-1}}. \tag{2.5}$$

The existence of equilibrium requires $\lambda \in [0,1]$ and this is satisfied for $\pi^I - K \geq \pi^J$. This leads to the first result.

Lemma 2.1. *The entry deterrence game has a unique symmetric equilibrium in pure strategies if $\pi^I(n) - K < \pi^J(n+k)$ in which no incumbent deters entry. If $\pi^I(n) - K \geq \pi^J(n+k)$, there is a unique symmetric equilibrium in mixed strategies where each firm deters entry with probability given by equation (2.5).*

Suppose from now on that $\pi^I(n) - K \geq \pi^J(n+k)$, so the symmetric equilibrium is in mixed strategies. This implies that incumbents would like to coordinate, irrespective of the mode of behavior. With positive probability, more than one firm erects an entry barrier in the mixed strategy equilibrium. Moreover, with probability $(1-\lambda^*)^n$ no firm deters entry and the value of each incumbent reduces to zero. It is easy to show that

Corollary 2.1. *The probability of entry $(1-\lambda^*)^n$ increases in the costs of entry deterrence and the profit firms earn upon entry. Entry becomes less likely if the incumbents' profits,* *the discount factor, or the number of potential firms increases. The effect of the number of incumbents on the probability of entry is ambiguous.*

Proof. The results simply follow by inspecting the relevant derivatives of $(1-\lambda *)^n$. These are

$$\begin{aligned}
\frac{\partial(1-\lambda^*)^n}{\partial K} &= \frac{n(\pi^I-\pi^J)(\lambda^*)^{\frac{2n-1}{n-1}}}{K^2(n-1)(1-\beta)} > 0,\\
\frac{\partial(1-\lambda^*)^n}{\partial \pi^I} &= -\frac{n(\lambda^*)^{\frac{2n-1}{n-1}}}{K(n-1)(1-\beta)} < 0,\\
\frac{\partial(1-\lambda^*)^n}{\partial \pi^J} &= -\frac{n(\lambda^*)^{\frac{n}{n-1}}}{(n-1)(\pi^I-\pi^J-\beta K)} > 0,\\
\frac{\partial(1-\lambda^*)^n}{\partial \beta} &= -\frac{nK(\pi^I-\pi^J-K)(\lambda^*)^{\frac{1}{n-1}}}{(n-1)(\pi^I-\pi^J-\beta K)^2} < 0,\\
\frac{\partial(1-\lambda^*)^n}{\partial n} &= -\frac{(\lambda^*)^{\frac{n}{n-1}}}{(n-1)^2}\left(\log(\lambda^*)+\frac{(n-1)n\left(\frac{\partial\pi^I}{\partial n}-\frac{\partial\pi^J}{\partial n}\right)}{\pi^I-\pi^J-\beta K}\right) \gtrless 0,\\
\frac{\partial(1-\lambda^*)^n}{\partial k} &= \frac{n(\lambda^*)^{\frac{2n-1}{n-1}}\frac{\partial\pi^J}{\partial k}}{K(n-1)(1-\beta)} < 0.
\end{aligned}$$

■

The most striking result is arguably the effect of an increase in k. This effect suggests a 'paradox of potential competition'. As the number of potential firms increases, the incumbents' profits upon entry decrease, and therefore they defend their market more vigorously. The effect of n is ambiguous because one cannot sign $\frac{\partial\pi^I}{\partial n}-\frac{\partial\pi^J}{\partial n}$ without additional information. However, when the mode of behavior is unaltered as new firms join the industry, this sign is exactly zero. Then, an increase in n has a 'crowding-out' effect on investment in entry deterrence. An increase in the number of incumbents aggravates the coordination problem.

2.4.2 Cartel stability

No cartel member should have an incentive to deviate from the collusive agreement about prices, quantities, or other strategic variables. Otherwise, collusion will not occur in equilibrium Collusive behavior and the associated stage profits π^C, can be sustained by a grim trigger strategy. Under this strategy, each firm reverts to static non-cooperative behavior 'forever' as soon as it observes that a cartel member deviated from the collusive agreement.

Firms do not coordinate on entry deterrence. This form of non-cooperative behavior within a cartel seems reasonable. If a non-rational firm defects from a price agreement, the other firms may discipline the firm by *temporarily* revert to the static Nash equilibrium. This enables the defector to learn about the workings of a cartel 'the hard way'. This type of learning is not possible if a firm deviates from an 'entry deterrence agreement'. Then, if a firm deviates, potential firms enter and the industry's profits decrease permanently.

Given that the cartel agreement is stable, each firm obtains a profit of π^C every market stage. As $\pi^C > \pi^N$, Corollary 2.1 implies that the probability of entry is lower for a cartel than for a non-cooperative industry, all other things equal.

For a stable cartel to exist, no firm should have an incentive to defect from the collusive agreement. Suppose one firm deviates at the market stage and obtains a profit π^D. All other firms respond by non-cooperative behavior in all future periods. Then, the cartel is stable if and only if

$$\pi^D(n) + \beta V^N(n) \leq \pi^C(n) + \beta V^C(n).$$

Using the expressions of V^N and V^C, this inequality can be rewritten as

$$\beta \geq \frac{\pi^D(n) - \pi^C(n)}{\pi^D(n) - \pi^N(n)}. \tag{2.6}$$

The above inequality gives all β's for which collusion can be sustained and is standard in the theory of industrial organization. The critical discount factor is defined to be the $\bar{\beta}(n)$ for which (2.6) holds with equality. Similarly, collusion is feasible after entry if

$$\beta \geq \frac{\pi^D(n+k) - \pi^C(n+k)}{\pi^D(n+k) - \pi^N(n+k)} \equiv \bar{\beta}(n+k). \tag{2.7}$$

The cartel breaks down upon entry if $\bar{\beta}(n) < \beta < \bar{\beta}(n+k)$.

The next proposition combines the above insights.

Proposition 2.1. *A cartel with finite expected cartel duration exists if* $\pi^C(n) - K > \pi^N(n+k)$ *and* $\bar{\beta}(n) < \beta < \bar{\beta}(n+k)$ *hold simultaneously.*

Clearly, the two conditions for finite cartel duration can hold simultaneously, because the critical discount factor $\bar{\beta}(n)$ is independent of K. Proposition 2.1 establishes that, even in an infinitely repeated game and perfectly rational actors, finite cartel duration may arise in equilibrium.

Cartel duration and cartel stability are closely related, but conceptually different, concepts. Despite this difference, many empirical studies of cartel duration simply point to theories of cartel stability to justify their selection of the determinants of cartel duration. Furthermore, the two notions are often used interchangeably in policy circles. This belief in the (observational) equivalence of cartel duration and cartel stability seems to be validated by Corollary 2.1. If, for instance, the incumbents' discount rate decreases (β goes up), the firms may be able to sustain collusion (β is pushed above the critical discount factor) and the probability of entry decreases. However, an increase in β may also have a more subtler effect. If collusion among the n incumbents is already feasible, an increase in β just nominally increases cartel stability, as it does not affect $\pi^C(n)$. Still, a higher discount factor may enable the firms to collude after entry if it pushes β above $\bar{\beta}(n+k)$. This implies a sharp increase in after-entry profits, from $\pi^N(n+k)$ to $\pi^C(n+k)$. By Corollary 2.1, this change in after-entry profits reduces the expected duration of the incumbents' cartel and therefore also the incumbents' expected expenditure on entry deterrence outlays. Hence, a policy that increases the stability of a cartel may *increase* welfare.

This example of the effects of a higher discount factor illustrates an important and surprising consequence of the model which deserves to be stated in an independent proposition.

Proposition 2.2. *A factor that fosters collusion among $n+k$ firms may contribute to the breakdown of a cartel consisting of n firms.*

Hence, the relation between cartel stability, cartel duration and welfare is intricate. Proposition 2.2 warns antitrust authorities to be careful when designing policies to combat collusion. A policy that makes collusion among $n+k$ firms less likely lowers $\pi(n+k)$ and therefore induces the incumbents to deter entry more vigorously. This results in an increased duration of the incumbents' cartel. By choosing to increase after-entry profits, but to keep before-entry profits constant, the policymaker chooses between the lesser of two evils.

The critical discount factor that sustains collusion before entry, $\bar{\beta}(n)$, is independent of K, the cost of deterring entry. This is an artifact of the model. Intuitively, one would expect that a positive endogenous probability of cartel breakdown hinders cartel stability because it requires a higher discount factor. One reason for why this intuition may be correct is that the cost of deterring entry could differ between modes of behavior. For instance, a cartel may have better political connections than a non-cooperative firm. As a result, a collusive firm would deter entry at a cost K^C, while a firm in a non-cooperative industry needs K^N to achieve the same result, where $K^N > K^C \geq 0$. In this case collusion is incentive compatible if and only if

$$\beta \geq \frac{\pi^D - \pi^C}{\pi^D - \pi^N + K^N - K^C} \tag{2.8}$$

and this increases in the difference between K^N and K^C. So, the more efficient a cartel is in deterring entry, the lower is its critical discount factor.

2.4.3 Entry deterrence as a participation game

The model is essentially an infinitely repeated participation game. In a participation game, players make an either/or choice, such as whether to enter a market or whether to save a drowning swimmer. In this chapter's model, a firm 'participates' when it chooses to deter entry. As shown by Anderson and Engers (2007) the symmetric equilibrium of a participation game is typically inefficient. In particular, in the symmetric equilibrium the equilibrium probability of entry deterrence, $1-(1-\lambda)^n$, is too low from the industry's perspective. That is, if the firms could commit to a probability λ with which each firm deters entry, they would choose a larger λ.

Proposition 2.1 establishes that finite cartel duration may occur in an infinitely repeated game. To derive this, the above analysis focused on the unique symmetric stationary equilibrium, which is in mixed strategies. However, participation games, like the current model, admit many equilibria, even in a one-shot game. See *e.g.* Palfrey and Rosenthal (1983) or Heijnen (2007). It would be interesting to see whether the main result of this paper carries over to other equilibria.

An infinitely repeated game may accommodate infinitely many equilibria. To somehow limit the number of possible equilibria, it seems reasonable–given the stationarity of the static game–to restrict attention to stationary equilibria. It is fairly easy to characterize the number of these equilibria. In each equilibrium, a set of firms never deters entry, and the remaining firms deter entry with some probability. That means that there are

$$\begin{aligned} \sum_{l=0}^{n-1} \binom{n}{l} &= \sum_{l=0}^{n} \binom{n}{l} - \binom{n}{n} \\ &= 2^n - 1 \end{aligned} \tag{2.9}$$

semi-mixed strategy equilibria in which l firms never deter entry, and the remaining $n-l$ firms randomize. There are exactly n pure strategy stationary equilibria, in which one firm deters entry, while the other incumbents enjoy a free ride. In the $2^n - n - 1$ remaining equilibria, at least two firms deter entry with some probability. Therefore, coordination problems also arise in those equilibria, and finite cartel duration does not rely on the symmetry postulate. Note that there can be many equilibria with entry. If, for instance $n = 10$, in 1013 of the 1024 equilibria entry is allowed with positive probability.

Of course, the market is not entered in any of the n stationary equilibria in pure strategies. These equilibria Pareto dominate the other equilibria, giving the incumbents a good reason to coordinate on that equilibrium. The firms may use a lottery to achieve this. The lottery selects a firm that is expected to deter entry at the x subsequent entry deterrence stages. After that, the firms organize a new lottery to pick a new 'volunteer'.

To study this lottery in more detail, suppose that at period 0, the cartel members organize a lottery and the losing firm's value V^l is

$$\begin{aligned} V^l &= \pi - K + \beta(\pi - K) + \ldots + \beta^{x-1}(\pi - K) + \frac{\beta^x V}{1-\beta} \\ &= \beta^x V + \frac{(\pi - K)(1-\beta^x)}{1-\beta}, \end{aligned}$$

where V is the value of each incumbent just before the lottery. Similarly, the value V^w of all other winning firms is

$$\begin{aligned} V^w &= \pi + \beta\pi + \ldots + \beta^{x-1}\pi + \frac{\beta^x V}{1-\beta} \\ &= \beta^x V + \frac{\pi(1-\beta^x)}{1-\beta}. \end{aligned}$$

Assuming that firms have an equal probability of losing, the expected value of each firm V obeys

$$V = \frac{1}{n}V^l + \frac{n-1}{n}V^w.$$

Solving the above equations for V gives

$$V = \frac{\pi - \frac{K}{n}}{1-\beta}. \tag{2.10}$$

The number of periods a firm needs to deter entry, x, drops out. Because firms are risk-neutral, they are indifferent between paying K/n for sure and paying K with probability $1/n$.

Coordination on this equilibrium can be quite valuable, as the value of each firm is strictly higher than in the symmetric mixed strategy equilibrium. It is natural to call the difference between these two values the *value of coordination*. Thus, the value of coordination is

$$\frac{\pi - \frac{K}{n}}{1-\beta} - \frac{\pi - K}{1-\beta}. \tag{2.11}$$

This difference is increasing in the number of firms, suggesting that the higher the number of firms, the more firms are willing to pay to be able to coordinate on this (correlated) equilibrium. The establishment of a trade union, for instance, could be a way to coordinate on the more profitable equilibrium. The above analysis may explain why industries with many firms are more likely to form trade unions.

2.5 Empirical implications

In this simple model all variables are stationary and, in the symmetric stationary equilibrium, the probability that a cartel breaks down is stationary too. Therefore, the duration of a cartel follows a geometric distribution, with probability density $(1-(1-\lambda)^n)^{t-1}(1-\lambda)^n$. The expected duration of the cartel is simply

$$\sum_{k=1}^{\infty} k(1-(1-\lambda)^n)^{k-1}(1-\lambda)^n = \frac{1}{(1-\lambda)^n}. \tag{2.12}$$

This could perhaps be used in empirical studies of cartel duration. Given that the economic model is correct, the probability that a given firm deters entry, on a yearly basis, can be calculated by using the expression for the expected duration. For instance, suppose that a cartel lasted for 10 years, and included 5 members. This corresponds to an expected value of $\lambda \approx 0.37$.

Another approach is to confront the model's comparative statics with the data. Do higher cartel profits translate to a higher cartel duration? Are more patient incumbents more inclined to deter entry? Relatedly, one could test whether cartel duration decreases in the number of incumbents. In an extensive study of 207 international cartels discovered between 1990 and 2004, Zimmerman and Connor (2005) find that the number of firms in a cartel is negatively related to cartel duration. However, other empirical studies obtain insignificant or even positive relations. For a summary of findings, see LS, Table 6.

More generally, the model's main message is that cartel duration is a phenomenon that can and should be modeled. By building a more sophisticated model of cartel duration, one could obtain a much richer set of empirical predictions. This is an important insight. Even though several empirical papers analyze the determinants of cartel duration, none is based on an equilibrium theory of cartel duration. As a result, the papers in this literature rather informally argue why their explanatory variables should be included in the statistical analysis. Variables that tend to facilitate collusion by increasing the critical discount factor are commonly interpreted as variables that tend to increase cartel duration.[4] This is a problematic interpretation, as pointed out in the discussion of proposition 2.2.

2.6 Extensions

2.6.1 Coordination failures between entrants

In the basic model, entry costs are zero, unless the incumbents invest. It seems more realistic to assume that entry costs are always positive, irrespective of the incumbents' behavior. When entry costs are positive, but not too large, a coordination problem between potential firms may arise. See for instance Elberfeld and Wolfstetter (1999) for a dynamic analysis of a related 'grab-the-dollar' game.

To study this case, adjust the model as follows. There are $k = 2$ potential firms. Their cost of entry is

$$c = \begin{cases} e & \text{if none of the incumbents invested} \\ +\infty & \text{if at least one incumbents invested,} \end{cases} \tag{2.13}$$

where $e > 0$. The timing is the same as in the basic model. In particular, the potential firms still decide simultaneously whether they enter. To keep the analysis interesting, assume that if there are n firms active, at most one firm can profitably enter. That is,

$$\frac{\pi(n+1)}{1-\beta} - e > 0$$

[4] As an illustration of this approach, consider Zimmerman and Connor (2005), who argue that "[e]conomic theory has long posited the significance of the effects of market structure characteristics on cartel duration. Empirical studies have since shown that a significant positive relationship exists between concentration and market share and cartel duration.", and "[c]onsistent with IO theory, markets possessing a large number of buyers allow for longer cartel duration [...]."

and

$$\frac{\pi(n+2)}{1-\beta} - e < 0.$$

As before, focus on symmetric stationary equilibria. Clearly, there is no equilibrium in pure strategies for the game between the potential firms. Let $\mu \in (0,1)$ denote the probability that a potential firm enters, conditional on that the entry costs are low. In a mixed strategy equilibrium, the potential firms must be indifferent between entering the market and staying out of it. If a firm does not enter, it obtains zero profits. Thus, the equilibrium condition is

$$\mu\frac{\pi(n+2)}{1-\beta} + (1-\mu)\frac{\pi(n+1)}{1-\beta} - e = 0.$$

This equation can be solved for the equilibrium μ^*:

$$\mu^* = \frac{\pi(n+1) - (1-\beta)e}{\pi(n+1) - \pi(n+2)}.$$

Now, consider the optimal strategy for the incumbents. As before, there will not be a symmetric equilibrium in which each firm deters entry with probability one. Suppose that none of the incumbents incurs the cost of entry deterrence. Then, given the mixed strategies of the potential firms, the value function of an incumbent is

$$V = (1-\mu^*)^2(\pi(n) + \beta V) + 2\mu^*(1-\mu^*)\frac{\pi(n+1)}{1-\beta} + (\mu^*)^2\frac{\pi(n+2)}{1-\beta}.$$

After substitution of μ^*, the above equation implicitly defines the equilibrium value V^* of the proposed equilibrium in which entry is not deterred. Suppose an incumbent deviates by deterring entry once. Its value becomes $\pi(n) - K + \beta V^*$. A symmetric equilibrium in pure strategies does not exist if

$$\frac{\pi(n) - K}{1-\beta} > V^*.$$

Since V^* is (proportional to) a weighted average of $\pi(n)$, $\pi(n+1)$ and $\pi(n+2)$, and profits are decreasing in n, this inequality holds if K is sufficiently small. In that case, the unique symmetric stationary equilibrium is in mixed strategies. As before, let λ denote the probability that an incumbent deters entry in a given period. In this equilibrium, the value of each incumbent V^{**} is implicitly defined by

$$(1-\lambda^*)^{n-1}\Big[(1-\mu^*)^2(\pi(n)+\beta V^{**}) \\ +2\mu^*(1-\mu^*)\frac{\pi(n+1)}{1-\beta}+(\mu^*)^2\frac{\pi(n+2)}{1-\beta})\Big] \\ +(1-(1-\lambda^*)^{n-1})\Big[\pi(n)+\beta V^{**}\Big]=\pi(n)-K+\beta V^{**}, \quad (2.14)$$

where as before the equality follows from the fact that firms should be indifferent between the two actions. The first term between square brackets is the continuation value of an incumbent when no other firm deterred entry. The second term denotes the continuation value when at least one incumbent deterred entry.

The introduction of positive entry costs induces a coordination problem between entrants. In turn, this lowers the incumbents' cost of a coordination failure. This can be seen from the first term between square brackets in (2.14), which decreases in μ^*. When the coordination problem between entrants is significant (μ^* is low), the incumbents deter entry with lower probability (λ^* goes down). Hence, positive entry costs mitigate the incumbents' entry deterrence problem.

2.6.2 Underinvestment in entry deterrence

In the basic model, where entry deterrence is modeled as a participation game, the probability with which incumbents deter entry is inefficiently low. This feature of the equilibrium extends to more general entry deterrence technologies. To show this, suppose that entry is deterred with probability $F(K)$, if the incumbents invest $K = k_1 + k_2 + \ldots + k_n$ and $F' > 0$ and $F'' < 0$. The investment of firm i is k_i.

Assume for simplicity that a symmetric equilibrium exists. Additionally, suppose that entry wipes out the profit of each incumbent. Given that firms decide non-cooperatively on entry deterrence, firm i would maximize

$$F(k_i + k^*(n-1))(\pi + \beta V) - k_i.$$

The first-order condition for a maximum is

$$f(nk^*)(\pi + \beta V) = 1.$$

If firms can coordinate on entry deterrence, they would maximize

$$F(nk^{**})(\pi + \beta nV) - nk^{**}.$$

The corresponding first-order condition is

$$f(nk^{**})(\pi + \beta nV) = 1.$$

Clearly, since F is concave, $k^{**} > k^*$. Just as in the participation game, firms in this version of the model are more likely to postpone entry when the cooperate. The main difference between the two models is that firms in this section's model follow pure strategies.

2.6.3 Finite cartel duration vs. collusive price wars

Green and Porter (1984) and Rotemberg and Saloner (1986) derive conditions under which a cartel would temporarily lower its price. In their models, collusion is stable, even when the cartel seems to have collapsed. Price wars simply ensure that collusion is an equilibrium. If a model exhibits finite cartel duration, cartels truly collapse after some time.

Although cartel duration and price wars are distinct concepts, the two can be studied simultaneously. An analysis of a model that features both finite cartel duration and price wars may yield additional insight in the determinants of cartel duration. In particular, since a model with price wars is non-stationary, in the sense that the continuation values of firms change over time, firms may have different incentives to deter entry during a price war. This may lead to a higher probability of cartel breakdown when the cartel is in a punishment phase. This intuition is correct, as the following simple extension shows.

Consider Tirole's (1988) version of the Green and Porter model with n symmetric incumbents. In Tirole's version, current market demand is zero with probability α, and $D(p)$ with probability $1 - \alpha$. The n incumbents compete by setting prices. Firms do not observe the price decisions of their competitors, only their realized profit. Tirole shows that, for β sufficiently large and α sufficiently small, this model has a collusive equilibrium. In the collusive phase of this equilibrium, firms charge the monopoly price until profits suddenly drops (as a result of the demand shock, in equilibrium). The firms revert to a temporary punishment phase, in which they obtain zero profits. After T periods, the firms reenter the collusive phase. During the collusive phase firms have a value of V^+ and at the start of the punishment phase their value is V^-.

Now, suppose that the incumbents in Tirole's model face a threat of entry. As in the above section, entry reduces each firm' profits to zero. (This can be thought of as a normalization.) Entry may be deterred by investing K such that entry is deterred with probability $F(K)$. Then, assuming a collusive equilibrium as described in the above paragraph exists, firm i maximizes

$$F(k_i + (n-1)k)\left((1-\alpha)(\pi^C + \beta V^+) + \alpha\beta V^-\right) - k_i$$

when it is in the collusive phase.

The first-order condition is

$$f(nk)\left((1-\alpha)(\pi^C + \beta V^+) + \alpha\beta V^-\right) = 1.$$

This gives a unique solution k^+. In contrast, if a firm is in the last period of the punishment phase, it maximizes

$$F(k_i + (n-1)k)\beta V^+ - k_i.$$

The corresponding first-order condition is

$$f(nk)\beta V^+ = 1,$$

which has a unique solution k^T, where the superscript T denotes the 'terminal' period of the punishment phase. The collusive profits of a firm in the terminal period of the punishment phase are deferred for one period. This implies that the solution k^T is strictly lower than k^+. As a result, a cartel is more likely to break down at the end of the punishment phase than in the collusive phase.

More generally, let Π_t be the value of a firm in period t of the punishment phase, where $1 \leq t < T$. Then, at the entry deterrence stage, this firm's value is

$$\Pi_t = \arg\max_{k_i} F(k_i + (n-1)k)\beta\Pi_{t+1} - k_i. \tag{2.15}$$

Since F and β are strictly smaller than one, $\Pi_t < \Pi_{t+1}$. Then, concavity of F implies that $k^t < k^{t+1}$. So, a firm is less eager to deter entry, the longer the remaining part of the punishment phase.

Hence, cartels are more likely to break down during price wars. In a price war, incumbents' continuation values are low, and therefore have little incentive to deter entry. This even holds when firms can coordinate on entry deterrence, because the cartel's continuation value is low as well during a price war.

The above insights complement Green and Porter (1984) analysis. They show

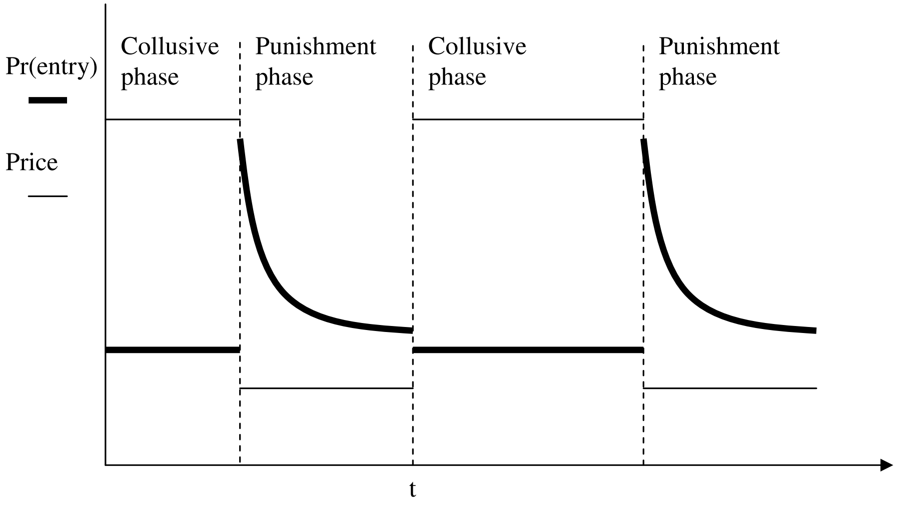


Figure 2.2. Equilibrium dynamics with unobservable demand.

that unobservable demand shocks may destabilize collusion, by increasing the critical discount factor that is necessary to sustain collusion and making price wars necessary in the optimal cartel agreement. The variation considered here demonstrates that unobservable demand shocks destabilize collusion by making entry more likely.

Figure 2.2 illustrates the dynamics of the model. During the collusive phase, firms coordinate on the high collusive price. Following a demand shock, or a defection by a cartel member, the firms enter the punishment phase and charge a price equal to marginal cost. During the punishment phase incumbents deter entry less vigorously and this implies an increase in the probability of entry. As the punishment phase nears its end, firms increase their effort to deter entry because it is more likely that they can reach a new collusive phase.

2.7 Concluding remarks

Cartel duration is one of the most important determinants of the welfare costs of collusion. Yet, it is also one of the least studied phenomena in IO theory. This chapter proposes a simple model to explain finite expected cartel duration. The basic framework is that of an oligopoly threatened by entry. Entry can be delayed, but it is costly to do so. The standard (static) models of entry deterrence are not suitable to study collusive behavior. Therefore, the model uses a repeated-game framework, which allows collusion to be an equilibrium phenomenon. Given that firms do not coordinate on entry deterrence, the incumbents may form a stable cartel that nevertheless breaks down with certainty.

The model yields several predictions about the determinants of cartel duration. For instance, an increase in the number of entrants leads incumbents to deter entry more vigorously and therefore to increase cartel duration. On the other hand, an increase in the number of incumbents tends to lower cartel duration. It is often thought that cartel stability and cartel duration are closely related, if not equivalent, notions. The results in this chapter demonstrate that a policy based on that belief may lead to sub-optimal welfare outcomes. The main insights of the model are robust to several extensions and alternative specifications, as shown in section 2.6. The basic model is simple, yet flexible, and can be adjusted to study cartel duration in various environments. It is, for instance, easy to include unobservable demand shocks to show that cartels are more likely to collapse during price wars.

The analysis suggests a number of policy implications. Antitrust authorities should direct their attention to cartels with the longer expected duration. The model provides a number of clues of how to determine this. An industry with a well-functioning trade union and excellent political connections will find it relatively easy to deter entry (K is relatively low). Additionally, a collusive industry which produces a good for which a large number of potential entrants exists (k is relatively high) will have a big incentive to prevent entry and, accordingly, a long expected duration. Instead of trying to end collusion directly, a policymaker may also attempt to decrease the duration of a cartel. This can be done by making access of firms to politicians more difficult or lowering import tariffs.

Whether entry really explains finite cartel duration is, ultimately, an empirical issue. This chapter offers just one possible explanation. For some cases the model is clearly too stylized to offer a convincing story. Consider, as an illustration, the case of a cartel that functions well for some time, dissolves, and re-establishes itself after a while. There are many examples of cartels that seem to have distinct episodes of collusive behavior. Perhaps the most famous example is the Joint Executive Committee, as studied by Porter (1983) and many others. In the basic model of this chapter, a cartel only exists for a finite period until new firms enter. Still, this seems to be fairly consistent with empirical regularities. In Suslow (2005), 31 cartels out of 45 cartels in manufacturing and commodity industries had just one episode. The Webb-Pomerene cartels reorganized even less frequently: only 16 of the 93 cartels had several cartel episodes (Dick, 1996).

As a suggestion for future work, it would be interesting to allow potential firms to enter the market sequentially. That presumably gives interesting dynamic patterns, in which the size of the cartel gradually increases, and suddenly disintegrates. Additionally, including a strategic antitrust authority that actively seeks to increase social welfare may help to understand the effects of leniency policies on cartel duration. The key explanation of cartel duration in this chapter is the threat of entry. Often, cartels seems to break down because of internal disagreements, as LS argue. It would be very worthwhile to explicitly include bargaining problems in a model of collusion.

Chapter 3

Antitrust enforcement without commitment

> Policing the collusion sounds very much like the subtle and complex problem presented in a good detective story.
>
> George J. Stigler (1964, p. 48)

3.1 Introduction

Fines are the main, and sometimes the only, sanction available to antitrust authorities. According to the economic theory of law enforcement, a fine should in principle be set such that the expected fine equals the net harm done to other parties.[1] The optimal fine induces firms to engage only in efficient collusion, and typically fully deters this form of anticompetitive behavior. This insight seems to be well understood by antitrust authorities. To illustrate, the European Commission's Guidelines state that fines should be set to "punish the firms involved and *to deter* (emphasis added) others from practices that infringe the competition rules".[2]

Antitrust authorities may not be able to adhere to this normative principle. European antitrust enforcement, for instance, is constrained by a cap on fines of 10 percent of the firm's annual turnover. A more fundamental issue is that antitrust authorities may not be able to commit to fines that deter collusion. After the antitrust authority has established the existence of a cartel and must decide on the

[1] See for instance Becker (1968), Landes (1983), or Polinsky and Shavell (2000).

[2] Commission Guidelines on the method of setting fines imposed pursuant to Article 23(2)(a) of Regulation (EC) No 1/2003.

appropriate fine, it has good reasons (and the authority) to lower it. Since the social welfare loss associated with a cartel is sunk, the optimal fine *ex post* is zero. As a result, without the ability to commit itself, the antitrust authority may be unable to deter collusion.

This chapter studies optimal antitrust enforcement when the government cannot commit to an antitrust policy.[3] The government, aiming to maximize social welfare, tackles this commitment problem by delegating enforcement to an antitrust authority with a biased objective function. The antitrust authority's objective function is biased in the sense that it may give consumer welfare and firm profits unequal weights. It is shown that it is optimal to delegate antitrust enforcement to an antitrust authority whose objective function is biased toward consumer welfare. This may explain why some antitrust authorities pursue to maximize consumer welfare, instead of social welfare, as some commentators argue.[4] For instance, Neven and Röller (2005) observe that "[i]t is striking that some of the major antitrust agencies appear to operate with objectives that differ from welfare maximization. In particular, both the U.S. as well as European merger control can be interpreted as maximizing consumer surplus rather than aggregate welfare." Recently, European Commissioner Kroes said that "We all agree that the overall aim of competition policy, including the application of Article 82 and Section 2 of the Sherman Act, is to protect consumer welfare."[5]

The analysis in this chapter naturally relates to the literature on antitrust enforcement. A crucial issue in these models is how one should model the behavior of the antitrust authority. The early contributions (see for instance Block, Nold and Sidak, 1981) assume that the probability of detection of a cartel by the antitrust authority is exogenous. Besanko and Spulber (1989) propose a model with incomplete information in which this probability is endogenous. They find that, even if the antitrust authority can perfectly establish the existence of a cartel and commit to any antitrust policy, it is optimal to allow some degree of collusion. The assumption of perfect commitment is typically discarded in subsequent work. In its place, theorists assume that the antitrust authority commits *ex ante* to some probability of investigation (*e.g* Motta and Polo, 2003) or that the antitrust authority investigates according to an arbitrary rule of thumb (Harrington, 2005). The model in this

[3] An antitrust policy is a complete description of the actions of the antitrust authority, at all possible information sets.

[4] Alternatively, one may argue that national antitrust authorities of small open economies *de facto* maximize consumer surplus given that the price-fixing firms are mostly multinationals.

[5] N. Kroes, "Exclusionary abuses of dominance – the European Commission's enforcement priorities", speech addressed at *Fordham University Symposium*, September 25, 2008.

chapter builds on Besanko and Spulber (1989). Their framework is useful because it captures two crucial ingredients of actual antitrust enforcement, namely asymmetric information about the firms' marginal costs and asymmetric information about their conduct (cooperative or non-cooperative). The main difference between this chapter and their work is that this chapter considers antitrust policy when the antitrust authority is unable to commit itself. In this chapter, the antitrust authority responds strategically to the behavior of the firms. Martini and Rovesti (2004) also consider antitrust enforcement in the absence of commitment. They assess the effectiveness of a consumer welfare standard with a social welfare standard. However, they suppose that an antitrust authority's investigation retroactively dictates non-cooperative behavior, which is tantamount to assuming the commitment problem away. This condition is not imposed in the analysis below. Moreover, the model in this chapter allows for a more general antitrust objective function, of which consumer welfare and social welfare are special cases.

This chapter also builds on the literature of strategic delegation. In an influential paper, Rogoff (1985) shows, in the context of monetary policy, that it may be optimal to delegate authority to a central banker with a greater distaste of inflation than the median voter. Besanko and Spulber (1993) and Neven and Röller (2005) analyze optimal standards for the antitrust authority in the context of merger analysis. See Carlton (2007) for a recent general discussion of the appropriate objective for antitrust authorities.

The remainder of this chapter is as follows. First, in section 3.2, the model is introduced. The main results are presented in section 3.3, where the full information benchmark (section 3.3.1) and the equilibrium under asymmetric information (section 3.3.2) are studied. Section 3.4 offers an analysis of alternative commitment devices (in section 3.4.1), internal cartel stability (in section 3.4.4) and leniency programs (section 3.4.5). Conclusion are relegated to section 3.5.

3.2 The model

3.2.1 Firms

There are $n \geq 2$ identical risk-neutral firms. Each firm produces a homogeneous good at marginal costs $\theta \geq 0$. The marginal costs are the same across firms and are either θ_h or θ_l, where $\theta_h > \theta_l \geq 0$. The government and the antitrust authority perceive costs as being θ_l with probability α and θ_h with probability $1 - \alpha$, where $\alpha \in (0, 1)$.

The firms face a market demand curve $Q(p)$. $Q(p)$ has a finite choke price $p^c > \theta_h$ above which demand is zero. Prices are publicly observable. The market price p is the minimum of the prices of all firms and p^c. Let p_{-i} be the minimum of the prices of all firms and p^c excluding firm i. Given that $p_{-i} < p^c$, firm i's gross profit (*i.e.* net of fines), is

$$\pi(p_i) = \begin{cases} 0 & \text{if } p_i > p_{-i} \\ \frac{1}{\#j:p_j=p_{-i}} Q(p_i)(p_i-\theta) & \text{if } p_i = p_{-i} \\ Q(p_i)(p_i-\theta) & \text{if } p_i < p_{-i} \end{cases}$$

After the firms observe their costs, they may either act non-cooperatively or act cooperatively and form a cartel. In the former case, the firms compete in a Bertrand-Nash fashion, which implies that the equilibrium market price is θ and each firm earns zero profits. If the firms collude, they agree to charge a price that maximizes their expected joint profits.[6] By assumption, a unique price $p^m(\theta)$ exists that maximizes $\pi = (p-\theta)Q(p)$. Additionally, this optimal price is assumed to be relatively high; $p^m(\theta_l)$ is strictly larger than θ_h. This implies, *inter alia*, that a low-cost industry cannot simultaneously mimic a high-cost non-cooperative industry and obtain unconstrained monopoly profits.

After the market stage, the antitrust authority may investigate the industry. An investigation yields legal evidence of the industry's conduct. Since collusion is strictly illegal *per se*, the antitrust authority may impose a penalty $F \in [0, A]$ on a collusive industry, where $A < \infty$. Fines may be bounded because firms enjoy limited liability.[7] To keep the analysis interesting, suppose that A is relatively large: $\pi^m(\theta_h) \leq A$. Otherwise, collusion would be impossible to deter.[8]

[6] To highlight the antitrust authority's commitment problem, internal cartel stability issues are ignored here. See, however, section 3.4.4 in which the individual firms' incentives to adhere to the cartel agreement are explicitly studied.

[7] In practice, antitrust law imposes restrictions on F as well. The Sherman Act, for instance, specifies a maximum fine of \$ 10,000,000 for corporations. Additionally, there seems to be a consensus among antitrust authorities that fines should not lead to a firm's bankruptcy.

[8] According to some economists, fines are often set too low to effectively deter collusion (see for instance Connor, 2004). If that were true, one would expect much more collusive activity than we currently perceive. Perhaps the maximum fine has a deterrent value for some industries, but not for others. The implication of this presumption is that the analysis in this chapter applies to those industries for which the maximum fine is relatively large.

3.2.2 The antitrust authority

The antitrust authority is supposed to deter collusion. The antitrust authority may investigate the industry at cost $K > 0$. The cost of investigation is relatively small; $K < \alpha A$. Since the antitrust authority neither observes θ nor the industry's conduct, it is without loss of generality to let $\beta(p) \in [0,1]$ be the probability that the antitrust authority investigates the industry, conditional on the market price.

The antitrust authority cannot commit to any arbitrary antitrust policy. This seems a reasonable assumption. *Ex post*, the antitrust authority has no incentive to impose a fine. Fines are just a transfer and, in the presence of collusion, not a remedy. Although many economists suppose that a convicted cartel reverts to non-cooperative behavior, there is no theoretical or empirical justification for this assumption.[9] Moreover, a high fine conflicts with other objectives of the antitrust authority or the government. For instance, a high fine may induce some firms to exit the market, leaving a higher concentrated industry with a high (non-cooperative) price. High fines may also lead to (temporary) unemployment, conflicting with the government's social objectives. The inability to commit may also derive from the fact that it is hard to fully describe an antitrust policy. Each industry is different and this makes it more likely that the antitrust authority deals with the industry on a case-by-case basis. Finally, the antitrust authority may not be able to commit when the *ex ante* optimal policy requires the antitrust authority to investigate with some probability. It is hard for outsiders to observe whether the antitrust authority was able to commit when it did not investigate a particular industry.

3.2.3 The government

The government aims to maximize social welfare, and views F as a pure transfer from firms to consumers. Then, social welfare W can be written as

$$W = E\left[\int_{p}^{p^c} Q(t)dt + Q(p)(p-\theta) - \beta(p)K\right]. \tag{3.1}$$

Just as the antitrust authority, the government cannot commit to an antitrust policy. However, the government can instruct the antitrust authority to maximize a biased social welfare function. More precisely, the government can choose the relative

[9] Thompson and Kaserman (2001) show that 85% of indicted firms regain their pre-indictment stock price within a year, suggesting that many price-fixers recommence their collusive activities. Bosch and Eckard (1991) estimate that of all firms indicted by the U.S. Department of Justice between 1962 and 1980, 14% were recidivists.

weight that the antitrust authority places on consumer welfare. One way to think about this is that the government delegates the task of antitrust enforcement to an agent with preferences that are biased from the government's. Let $\lambda \in [0,1]$ be the relative weight of consumer welfare in the antitrust authority's objective function. Then, the antitrust authority maximizes

$$\tilde{W} = E\Big[\lambda\left(\int_p^{p^c} Q(t)dt + F\right) + (1-\lambda)\left(Q(p)(p-\theta) - F\right) - \beta(p)K\Big]. \tag{3.2}$$

3.2.4 Timing

The timing is as follows. First, the government chooses the objective function of the antitrust authority. Then, the firms privately learn their costs. They may commit to form a cartel. The firms subsequently set prices. Given these prices, the antitrust authority may investigate the firms. If it finds evidence of collusive behavior, it can impose a fine. Figure 3.1 depicts the game in extensive form.

3.3 The equilibrium

3.3.1 The full information benchmark

Consider antitrust policy when the antitrust authority simply knows the industry's marginal costs and perfectly observes the mode of behavior. This game can be solved by backward induction. The antitrust authority investigates a collusive industry if and only if $\lambda F - (1-\lambda)F - K > 0$. Clearly, if $\lambda < 1/2$, the antitrust authority sets the lowest possible fine. In this case, the antitrust authority never investigates and collusion cannot be deterred. If $\lambda \geq 1/2$, the antitrust authority sets $F = A$ and investigates if and only if

$$\lambda \geq \frac{A+K}{2A}. \tag{3.3}$$

Let $V(p,\theta) \equiv \int_p^{p^c} Q(t)dt + Q(p)(p-\theta)$. Then, social welfare is $E[V(\theta,\theta)]$ if (3.3) holds and $E[V(p^m(\theta),\theta)]$ otherwise. Social welfare is maximized if the antitrust authority induces non-cooperative behavior without actually investigating the industry. The government can achieve this by choosing a bias such that inequality (3.3) is satisfied. Therefore, with full information, the government selects a biased antitrust authority and collusion does not occur.

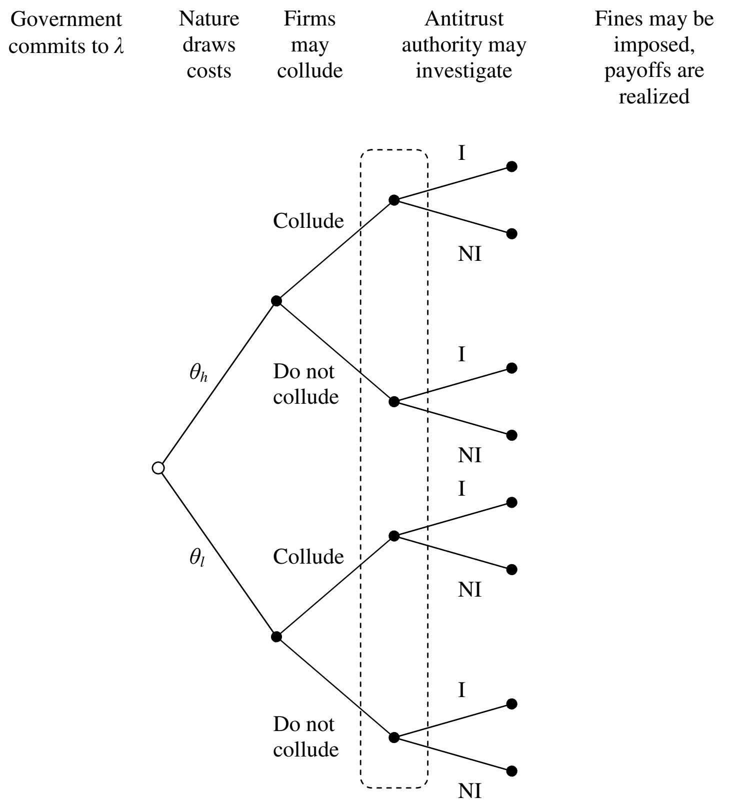


Figure 3.1. The timing of actions and events.

3.3.2 Equilibrium antitrust policy

It turns out that this no-collusion result no longer holds when the antitrust authority cannot observe the industry's marginal costs or conduct. Before deriving the equilibrium, it may be useful to introduce some additional functions. Let $\gamma(\theta;\lambda) : \{\theta_l, \theta_h\} \rightarrow [0,1]$ be the probability that firms collude given their cost parameter θ and λ. Additionally, let $\beta(p;\lambda) : [\theta_l, p^c] \rightarrow [0,1]$ be the probability that the antitrust authority investigates the industry after observing price p. In equilibrium, firms maximize expected profits by choosing γ and prices, the antitrust authority maximizes $\tilde{W}$ by setting β and the government optimally selects λ. For all players must hold that their strategies are optimal given their beliefs about their information and the other players' strategies. Players must update their beliefs according Bayes' rule whenever applicable.

Suppose first the government chooses a relatively low bias. Then it is straightforward to show the following.

Lemma 3.1. *Let* $\lambda \in \left[0, \frac{A+K}{2A}\right]$*. Then, the subgame between the industry and the antitrust authority has a unique (pooling) equilibrium in which both types collude by setting* $p^m(\theta)$ *and the antitrust authority never investigates. Hence,* $\gamma(\theta;\lambda) = 1$ *for* $\theta \in \{\theta_l, \theta_h\}$ *and* $\beta(p,\lambda) = 0$ *for any* $p \in [\theta_l, p^c]$*. The government's payoff is* $W_1 = E[V(p^m(\theta), \theta)]$*.*

Proof. Given the value of λ, it is not rational for the antitrust authority to investigate the industry, irrespective of its beliefs. The firms anticipate this and collude for both realizations of the cost parameter. ■

The government may also select an intermediate bias. This reduces the likelihood of collusion, as the next lemma states.

Lemma 3.2. *Let* $\lambda \in \left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right]$*. Then, the subgame between the industry and the antitrust authority has a unique (separating) equilibrium in which the low type colludes and the high type acts non-cooperatively. Both types set a price* θ_h *and the antitrust authority does not investigate collusion. In the equilibrium of this subgame,* $\gamma(\theta_l;\lambda) = 1$*,* $\gamma(\theta_h;\lambda) = 0$*,* $\beta(\theta_h;\lambda) = 0$ *and* $\beta(p;\lambda) = 1$ *for any* $p \neq \{\theta_l, \theta_h\}$*. The government's payoff is* $W_2 = \alpha V(\theta_h, \theta_l) + (1-\alpha)V(\theta_h, \theta_h)$*.*

Proof. Suppose that the antitrust authority observes $p = p^m(\theta_h)$. It rationally expects that this price originates from a collusive high type. Given its relatively high bias, it is inclined to investigate the industry and impose a fine. A high-cost industry anticipates this behavior and will not set such a price. The high type might consider a price $p \neq p^m(\theta_h)$. However, the antitrust authority knows that exclusively θ_l and θ_h will be observed in a non-cooperative equilibrium. Since setting price below costs is not profitable, high types will not collude in this subgame.

For the same reasons, a low type will not choose $p = p^m(\theta_l)$. Suppose it colludes with certainty and sets $p = \theta_h$. Then, the antitrust authority believes that it faces a collusive low type with probability α and a non-cooperative high type with probability $1-\alpha$. Given this belief, investigation will not be worthwhile as the expected payoff of an investigation is

$$\alpha(\lambda A - (1-\lambda)A - K + (1-\alpha)0 < 0$$

for λ in the assumed interval. ■

Finally, the government may select a relatively high bias. This gives an additional decrease in the probability of collusion.

Lemma 3.3. *Let $\lambda \in \left(\frac{A+K/\alpha}{2A}, 1\right]$. Then, the subgame between the industry and the antitrust authority has a unique (semi-separating) equilibrium in which the low type colludes with probability*

$$\beta(\theta_l; \lambda) = \frac{(\theta_h - \theta_l)Q(\theta_l)}{A}$$

and the high type acts non-cooperatively. The antitrust authority investigates $p = \theta_h$ with probability

$$\gamma(\theta_h; \lambda) = \frac{K - \alpha K}{2\alpha\lambda A - \alpha A - \alpha K}$$

and $\gamma(p; \lambda) = 1$ for $p \neq \{\theta_l, \theta_h\}$. Expected social welfare becomes

$$W_3 = \alpha(1 - \gamma(\theta_h; \lambda))V(\theta_l, \theta_l) + \alpha\gamma(\theta_h; \lambda)V(\theta_h, \theta_l) + \\ (1 - \alpha)V(\theta_h, \theta_h) - \beta(\theta_l; \lambda)(1 - \alpha + \alpha\gamma(\theta_h; \lambda))K.$$

Proof. As in the subgame with an intermediate bias, the high type will not form a cartel. Suppose the low type forms a cartel with certainty in equilibrium. Then, given the high bias, it will be optimal for the antitrust authority to investigate $p = \theta_h$ with certainty. As a result, this subgame will not feature an equilibrium in which the low type always colludes. Suppose the low type never colludes in equilibrium. Then, the antitrust authority interprets $p = \theta_h$ as a signal that costs are high and will not investigate. But then it is optimal for the low type to collude! Hence, the equilibrium in this subgame must be in mixed strategies. The low type is indifferent between collusion and competition if and only if

$$(\theta_h - \theta_l)Q(\theta_h) - \beta(\theta_l; \lambda)A = 0.$$

The antitrust authority is indifferent between investigating upon observing $p = \theta_h$ if and only if

$$\frac{\alpha\gamma(\theta_h; \lambda)}{1 - \alpha + \alpha\gamma(\theta_h; \lambda)}(\lambda A - (1 - \lambda)A) - K = 0.$$

Solving these equations gives the equilibrium probabilities β and γ. ■

Using the above insights, it is straightforward to show that

Proposition 3.1. *The government delegates enforcement to an antitrust authority with* *an objective function that is biased toward consumer welfare. For $\alpha \leq \alpha^*$ the game has a separating equilibrium, where*

$$\alpha^* \equiv \frac{K\int_{\theta_l}^{\theta_h} Q(t)dt + (A-K)Q(\theta_h)(\theta_h - \theta_l)}{A\int_{\theta_l}^{\theta_h} Q(t)dt} \in (0,1).$$

In this case, the optimal bias is any λ in $\left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right]$. For $\alpha > \alpha^*$ the equilibrium has a semi-separating equilibrium in which the low-cost type pools with some probability with the high-cost type and the optimal bias λ is 1.

Proof. The government is the first to move in the game and will select the value of λ that maximizes expected social welfare. It is straightforward to show that W_1, the expected level of social welfare as found in lemma 3.1, is strictly dominated by W_2. Substituting the equilibrium values of $\gamma(\theta_h;\lambda)$ and $\beta(\theta_l;\lambda)$ for the subgame with $\lambda \in \left(\frac{A+K/\alpha}{2A}, 1\right]$ into W_3, one can show that W_3 is strictly increasing and concave in λ. Furthermore,

$$W_2 - W_3|_{\lambda=\frac{A+K/\alpha}{2A}} = \frac{KQ(\theta_h)(\theta_h - \theta_l) + A(1-\alpha)Q(\theta_h)(\theta_h - \theta_l)}{A}.$$

Hence, social welfare strictly decreases as λ moves from the second interval to the third interval. The government's choice is therefore between W_2 and W_3 for $\lambda = 1$. The difference between these levels is

$$\frac{(K-\alpha A)\int_{\theta_l}^{\theta_h} Q(t)dt + (A-K)Q(\theta_h)(\theta_h - \theta_l)}{A-K}$$

and this is positive if $\alpha < \alpha^*$. ■

3.3.3 Discussion of the equilibrium

Figure 3.2 depicts social welfare as a function of λ.

Social welfare is non-monotonic in λ. A relatively low bias does not deter collusion because the antitrust authority has no incentive to investigate. Increasing the bias induces the high type to act non-cooperatively and the low type to collude by mimicking the high type. This yields a strict increase in social welfare as both firms lower their price, and the antitrust authority does not investigate. By increasing the bias even further, the third scenario is entered in which the low-cost type and the antitrust authority randomize their actions. Although this initially reduces social welfare, social welfare is strictly increasing in λ in this interval. It may even be op-

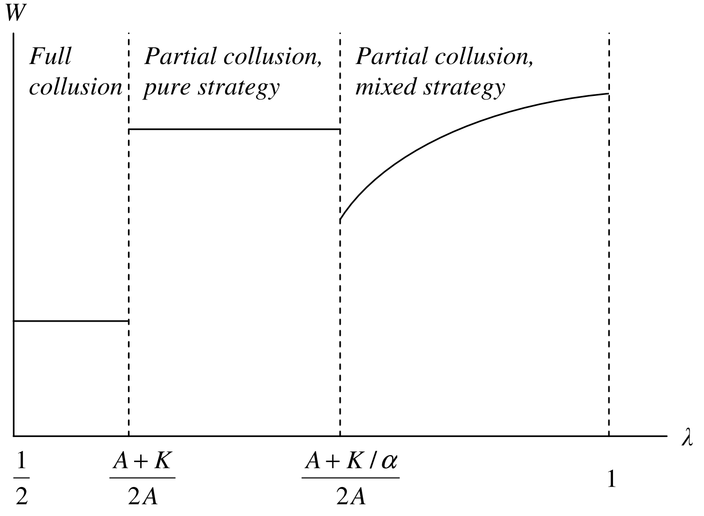


Figure 3.2. Social welfare with a biased antitrust authority.

timal to delegate enforcement to an antitrust authority who maximizes consumer welfare if the *ex ante* probability that firms have low costs if sufficiently high.

Observe that, even if λ is chosen optimally, collusion cannot be perfectly deterred. In each of the three cases, the firms collude to some extent. The lowest 'degree of collusion' can be found in the third case, in which only the low type colludes with some probability. This probability is still positive for $\lambda = 1$.

The degree of collusion decreases in K and λ. Hence, a more efficient antitrust authority obtains a higher level of social welfare. In principle, collusion could be perfectly deterred by letting $\lambda \to \infty$. This requires the antitrust authority to *minimize* the industry's profits, and seems politically infeasible. A better way to reduce the incidence of collusion is to increase the maximum fine A. In the limit, as $A \to \infty$, this perfectly deters collusion as well.

In equilibrium, the government chooses a positive bias to overcome the commitment problem. This may explain why actual antitrust authorities maximize consumer welfare, instead of social welfare. However, this result should not be interpreted as a policy prescription. Although the optimal bias is positive, it is easy to find alternative parameter configurations for which this result fails. For instance, if $\pi^m(\theta) > A$, it is optimal to select $\lambda = 1/2$, because otherwise the antitrust authority engages in ineffective and costly investigations. The optimal bias depends on institutional variables (A, K) and industry characteristics (α, π), and a one-sizefits-all solution seems therefore unavailable. A more fundamental reason is that the normative policy prescription from the economic analysis of law enforcement still applies. Fines should be set such inefficient harmful acts are deterred. Antitrust authorities should commit to this principle by, *e.g.*, building a reputation of tough law enforcers.

The idea of appointing an agent with biased preferences to solve the commitment problem is borrowed from the central banking literature. It is striking to observe that our model recommends to choose an agent with what one could describe as 'left-wing' preferences, whereas the central banking literature advises to hire an agent with 'right-wing' preferences.

3.4 Extensions

3.4.1 Building a reputation

It may be difficult in practice to determine the optimal bias. If so, the inability to commit (to the optimal antitrust policy) implies that each industry type engages in unconstrained collusion. As noted above, the antitrust authority may preclude this by building a reputation. However, the notion of reputation is rather vague. The aim of this section is to clarify how antitrust authorities may build and maintain a reputation of a vigilant cartel fighter.

In common parlance, an agent is usually said to have a reputation if he or she is able to forgo short-run gains to secure high long-run gains. In game-theoretical parlance, there may be two types of reputation; the 'equilibrium' interpretation and the 'adverse selection' interpretation (Samuelson, 2006). In the former approach, one considers an infinitely repeated game, and selects a particular equilibrium that has the desired 'reputation-like' features. In the latter approach, the agent is privately informed about its type and may mimic the behavior of a strong type if he or she is weak.

3.4.2 Equilibrium reputation

As an example of reputation under the 'equilibrium' interpretation, consider an infinitely repeated game version of the model. Suppose that the antitrust authority and the firms have a common discount factor $\delta \in (0, 1)$ and maintain the assumption that $\pi^m(\theta) \leq A$. The proposed equilibrium features 'reputation', in the sense that the antitrust authority investigates any price $p \neq \theta_l$ and firms do not collude. This equilibrium could be supported by the antitrust authority's belief that, if it deviates, both cost types collude 'forever'. The equilibrium exists if the value of investigating conditional on observing $p = \theta_h$ is larger than the value of not investigating. The value of maintaining an equilibrium is

$$-K + \frac{\delta}{1-\delta}\left[\alpha V(\theta_l,\theta_l) + (1-\alpha)(V(\theta_h,\theta_h) - K)\right].$$

If the antitrust authority refrains from investigating $p = \theta_h$, its value is

$$E\left[\frac{\delta}{1-\delta}V(p^m(\theta),\theta)\right].$$

It is straightforward to show that the proposed equilibrium exists if and only if

$$\delta \geq \frac{K}{E\left[V(\theta,\theta) - V(p^m(\theta),\theta)\right]}.$$

So, if the antitrust authority is sufficiently patient, it may maintain a reputation. The proposed equilibrium has reputation-like features, as the antitrust authority loses its reputation when it fails to investigate.

3.4.3 Adverse selection reputation

The model can also be adjusted to allow for 'adverse selection' reputation. More specifically, assume the model of section 3.2 is repeated twice and players do not discount the future. For simplicity, suppose that the antitrust authority is unbiased, *i.e.* $\lambda = 1/2$. Firms are incompletely informed about the antitrust authority's type. The antitrust authority may be strong, and have zero investigation costs, or be weak, and have a positive cost of investigation K. Suppose that the firms *ex ante* belief is that both possibilities are equally likely. In this setting, there may be a pooling equilibrium in which both antitrust authorities (*i.e.* the strong and the weak type) investigate in the first period and firms act non-cooperatively in both periods.

To see this, note first that a strong antitrust authority has a (weakly) dominant strategy to investigate each price. A weak antitrust authority investigates a price θ if and only if

$$2E\left[V(\theta,\theta)\right] - K \geq E\left[V(\theta,\theta) + V(p^m(\theta),\theta)\right],$$

or if

$$K \leq E\left[V(\theta,\theta) - V(p^m(\theta),\theta)\right].$$

If a weak antitrust authority deviates from the proposed equilibrium, the firms (correctly) believe that the antitrust authority is weak and collude in the second period. Additionally, firms should not find it optimal to collude in the first period. This holds if $\pi^m(\theta) - \frac{1}{2}A \leq 0$.

In the proposed pooling equilibrium, a weak antitrust authority builds a reputation by mimicking a strong antitrust authority.

3.4.4 Antitrust enforcement and cartel stability

So far, the matter of internal cartel stability is ignored. A cartel agreement is internally stable if no cartel member is tempted to deviate from it. In the one-shot model of section 3.2, an agreement to set a price above marginal costs is unstable. Given that all other firms adhere to the collusive price, a firm could dramatically boost its profit by slightly undercutting this price. Each firm understands this temptation and the market price is driven down to marginal costs. The aim of this section is to include the restriction that cartel agreements should be stable.

To enable the firms to enter into stable agreements, adjust the model in the following way. The game is infinitely repeated and firms discount payoffs with common discount factor $\delta \in (0,1)$. Marginal costs are distributed independently across periods.[10] Firms observe only their current marginal costs. As is well-known, repeated games typically admit multiple equilibria, or an 'embarrassment of riches'. One such equilibrium is encountered in section 3.4.1 of the repeated game in which the antitrust authority maintains a reputation. To select a subgame perfect equilibrium, assume that the firms coordinate on the profit-maximizing agreement and the antitrust authority myopically maximizes its objective function.

Before the equilibrium of the adjusted model is derived, note first that defection by a cartel member informs the antitrust authority that a cartel exists. If consumers can observe that a firm undercuts the current market price, then so can the antitrust authority.

Just as in section 3.3.2, the model is solved by considering the equilibria of the

[10] This assumption is clearly restrictive. However, if marginal costs evolve deterministically, plus some additive random term, then the independence assumption can be reinterpreted by viewing the firms' private information as knowledge of the random term.

subgames for given values of λ. For

$$\lambda \in \left[0, \frac{A+K}{2A}\right],$$

the antitrust authority never investigates and the remaining constraint to consider is the firms' incentive compatibility condition. This is

$$\frac{1}{n}\pi^m(\theta_k) + \frac{1}{n}\frac{\delta}{1-\delta}E[\pi^m(\theta)] \geq \pi^m(\theta_k)$$

for $k = l, h$. This can be rewritten as

$$\delta \geq \frac{(n-1)\pi^m(\theta_k)}{E[\pi^m(\theta)] + (n-1)\pi^m(\theta_k)}. \tag{3.4}$$

Collusion is hardest to sustain for $\theta = \theta_l$. Condition (3.4) can therefore be ignored if the firms have high marginal costs.

If

$$\lambda \in \left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right],$$

both types set $p = \theta_h$ in the one-shot game. This also holds in the repeated game, because the antitrust authority plays the optimal one-shot Nash response. The incentive compatibility condition is

$$\frac{1}{n}Q(\theta_h)(\theta_h - \theta_l) + \frac{\alpha}{n}\frac{\delta}{1-\delta}Q(\theta_h)(\theta_h - \theta_l) \geq Q(\theta_h)(\theta_h - \theta_l) - \frac{A}{n}.$$

Observe that, if a firm defects, the antitrust authority learns that a cartel exists and imposes a fine A on the industry, which is equally borne by all firms. The incentive constraint can be rewritten as

$$\delta \geq \frac{(n-1)Q(\theta_h)(\theta_h - \theta_l) - A}{(n-1+\alpha)Q(\theta_h)(\theta_h - \theta_l) - A} \equiv \bar{\delta}. \tag{3.5}$$

Interestingly, a higher maximum fine may have perverse effects on the firms' ability to collude.

Proposition 3.2. *An increase of the maximum fine A fosters collusion if*

$$\lambda \in \left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right].$$

Proof. The result simply follows by observing that the critical discount factor $\bar{\delta}$ decreases in A. ■

Antitrust policy helps firms to form a cartel because defection is immediately punished by the antitrust authority. As soon as a firm deviates from the cartel agreement, the rational antitrust authority learns that a cartel exists, launches a successful investigation and imposes a fine on all firms, including the defector. This strategic response of the antitrust authority makes defection less attractive, and thereby collusion more stable. Various authors (*e.g.* Motta and Polo, 2003) have observed similar pro-collusive effects of well-intended antitrust legislation.

Finally, suppose the antitrust authority's bias is

$$\lambda \in \left(\frac{A + K/\alpha}{2A}, 1\right].$$

Then, as argued above, the equilibrium of the one-shot game is in mixed strategies. Each firm expects zero profits under the collusive agreement. If the firms have decided to collude and charge θ_h, a firm that contemplates to deviate adheres to the collusive price if and only if

$$\frac{1}{n}\left((\theta_h - \theta_l)Q(\theta_h) - \beta A\right) \geq (\theta_h - \theta_l)Q(\theta_h) - \frac{A}{n}.$$

Given the zero-profit constraint, this incentive compatibility condition boils down to $A \geq Q(\theta_h)(\theta_h - \theta_l)$ which is always satisfied. The analogue of proposition 3.1 is

Proposition 3.3. *In equilibrium of the modified (repeated-game) model, the government delegates enforcement to an antitrust authority with an objective function that is biased toward consumer welfare. The optimal bias λ is 1 if $\alpha > \alpha^*$ and $\delta \geq \bar{\delta}$ hold simultaneously. Otherwise, the optimal bias is any λ in $\left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right]$. Expected social welfare per period attains its maximum $E[V(\theta, \theta)]$ if $\delta < \bar{\delta}$.*

Proof. First, suppose that $\delta \geq \bar{\delta}$. Then, a collusive agreement under which the low type mimics the non-cooperative high type can be sustained. Since the implicit assumption of the basic model is that cartels are always stable, proposition 3.1 can be applied directly to find the optimal bias. Second, suppose $\delta < \bar{\delta}$. A collusive agreement in pure strategies is no longer feasible. Given that $\lambda \in \left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right]$, the firms cannot collude when their costs are low. To see this, suppose that a low type colludes with some probability γ. Then, the critical discount factor $\bar{\delta}$ *increases* in γ. As a result, firms always behave non-cooperatively. Social welfare in this case is $E[V(\theta, \theta)]$ per period, and this cannot be improved. ■

Perhaps the most interesting implication of proposition 3.3 is that an antitrust authority's bias should be relatively low when firms are unable to profitably collude. By keeping the bias low, the government induces non-cooperative market conduct. It must be emphasized that this result hinges on the assumption that the firms are sufficiently impatient. When, as seems more realistic, firms are sufficiently patient, it may be optimal to *increase* the antitrust authority's bias, as the next section illustrates.

3.4.5 Leniency programs

Following the success of the U.S. Antitrust Division's *Corporate Leniency Program*, many national antitrust authorities have adopted similar policies, by granting partial or full fine reduction to firms that voluntarily report their cartel. A few recent papers examine the effects of leniency on cartel stability, see for instance Spagnolo (2004) or Aubert, Rey and Kovacic (2006). The general finding that emerges from this literature is that leniency programs help to deter collusion. However, these models typically assume that the antitrust authority does not act strategically, by supposing that the antitrust authority commits to a fixed probability of detection. The premise of the current chapter is that antitrust authorities act strategically and without commitment. It would be very interesting to consider the desirability of a leniency policy in such an environment, and that is exactly the aim of this section.

As above, suppose that the basic game of section 3.2 is infinitely repeated. The government endows the antitrust authority with some bias λ and imposes a leniency program. This program gives full immunity to prosecution for any firm that reports a cartel. When a firm informs the antitrust authority of the existence of a cartel, the antitrust authority still needs to investigate this case at some cost. It seems reasonable to suppose that the cost of investigation is lower when one cartel member cooperates. To uncover the pure effect of the leniency program on the incentive to collude, however, it is helpful to make a conservative estimate of the investigation cost. In particular, let this cost be K, irrespective of whether a firm collaborates with the authorities.

To see how these assumptions affect the equilibrium, observe that a leniency program has no effect when $\lambda \in \left[0, \frac{A+K}{2A}\right]$, as in that case the antitrust authority does not investigate the industry and a leniency program has no 'bite'. For $\lambda \in \left(\frac{A+K}{2A}, \frac{A+K/\alpha}{2A}\right]$, a leniency program has a destabilizing effect on cartels. This follows directly from proposition 3.2, which establishes that an increase in the maximum fine lowers the critical discount factor. Granting leniency to a firm that simultaneously cheats on the cartel agreement and reports the cartel to the antitrust authority increases the critical discount factor to

$$\bar{\delta}_{LP} = \frac{(n-1)Q(\theta_h)(\theta_h - \theta_l)}{(n-1+\alpha)Q(\theta_h)(\theta_h - \theta_l)}.$$

For $\lambda \in \left(\frac{A+K/\alpha}{2A}, 1\right]$, the effect of a leniency program is even stronger. By simultaneously deviating and reporting, a defector earns $Q(\theta_h)(\theta_h - \theta_l)$. The value of adhering to the cartel agreement is zero, given the use of mixed strategies. Hence, the cartel's incentive compatibility condition is $(\theta_h - \theta_l)Q(\theta_h) \leq 0$, which cannot be satisfied.

The observations imply the following result.

Proposition 3.4. *A consumer welfare standard, combined with a leniency program, is sufficient to induce the non-cooperative equilibrium.*

By choosing a consumer welfare standard, *i.e* setting $\lambda = 1$, a collusive industry is restricted to use mixed strategies. The leniency program ensures that this strategy is unstable. So, the antitrust authority's bias and the leniency program are complementary. If the government chooses to use just one instrument, it would have to tolerate some degree of collusion. Proposition 3.4 rationalizes, or at least sheds more light on actual antitrust enforcement policy.

3.5 Concluding remarks

There is no reason to suppose that antitrust authorities have the ability to commit to an antitrust enforcement policy. Even in relatively simple models, optimal enforcement requires a commitment to a set of intricate and industry-specific probabilities of investigation and fine functions. It seems more realistic to suppose that antitrust authorities try to deter collusion on a case-by-case basis. Responding to suspicious pricing behavior, and imposing fines that are optimal *ex post*, the antitrust authority effectively operates without commitment.

Given that fines are perceived as welfare-neutral transfers, an antitrust authority that cannot commit would refrain from setting a fine, enabling firms to engage in unconstrained collusion. To prevent this from occurring, the government, or a social planner, can appoint an agent with preferences biased toward consumers to head the antitrust authority. This agent does not perceive fines as mere transfers and therefore does not shy away from imposing the maximum fine on firms that have been found guilty of price-fixing.

Welfare is shown to be non-monotonic in the agent's bias. Nevertheless, the optimal bias is always positive: the government hires an agent whose preferences are biased toward consumer welfare. This finding may explain why some antitrust authorities seem to maximize consumer welfare, instead of social welfare. A practical constraint of the delegation solution is that it may be difficult to select the optimal bias, especially when the optimal bias lies somewhere in the mysterious realm between the social welfare standard and the consumer welfare standard.

An alternative interpretation of a preference bias is that the government gives the antitrust authority an explicit incentive contract. This contract may stipulate higher wages if the observed degree of collusion is low, or the revenue from fines is high.

Even if the antitrust authority is run by an agent with an optimal bias, firms are still able to collude. This is not caused by the antitrust authority's inability to commit however. Institutional constraints, such as a limit on the maximum fine, prevent the antitrust authority to fully deter price-fixing. By explicitly modeling the cartel members' incentive to adhere to the collusive agreement, it can be shown that leniency programs, combined with a consumer welfare standard, induce the non-cooperative equilibrium. This suggests that leniency programs are most successful when the antitrust authority actively investigates potentially colluding industries.

For future research, it would be interesting to relax a few technical assumptions. More specifically, the firms in this chapter have common marginal costs, their private information is binary and that marginal costs are independently distributed across periods. Much realism can be gained by allowing for a continuum of marginal costs or by considering persistent marginal costs.

Chapter 4

Price fixing and non-price competition

> When a uniform price is agreed upon, or agreed to by, an industry, some or all of the other terms of the sale are left unregulated. [...I]n the absence of free entry [...] the question arises: Will any monopoly profit achieved by suppressing price competition be eliminated by non-price competition?
>
> George J. Stigler (1968, p. 149)

4.1 Introduction

The typical industrial organization model of collusion considers the case where firms collude fully on every single aspect of their products. In practice, however, firms are often only able to collude on a limited number of dimensions. Shops that have agreed on a high price for their merchandise will be inclined to exert more effort to secure a sale from a customer that has entered their shop. Construction firms that collude on prices are still able to unilaterally decide on the amount of effort they put in proposing a plan to suit the tastes of the customer they are facing. In these examples, price fixing firms conspire against the consumer, but still compete against each other in the quality dimension.

This chapter is based on joint work with Marco Haan.

Empirical research suggests that, indeed, firms collude primarily by fixing prices rather than coordinating on other aspects of their product. For instance, in his study of post-war British cartels, Symeonidis (2002, p. 35) argues that "The British cartels were primarily price fixing bodies. Regulation of non-price decisions was uncommon". Another example is the American cigarette industry in the 1920s and 1930s. There, according to Fershtman and Gandal (1994), the three major firms colluded on price but competed on advertising to garner more sales.

It is unclear why most cartels restrict themselves to price agreements. A possible explanation could be that agreements about quality require laborious product descriptions. These descriptions are not only costly to write, but may also be used by the antitrust authority as evidence of collusive behavior.[1] An alternative explanation is offered by Deltas and Serfes (2002). They show that semicollusion may be more profitable than full collusion when demand is stochastic and the collusive agreement inflexible.

The focus of this chapter is not to provide an explanation of price fixing. Instead, price fixing behavior is taken as given and firms are assumed to compete on quality. This chapter studies the effect of this behavior on prices, product quality, profits, and welfare. One immediate question that arises is to what extent such price fixing still enables firms to increase their joint profits. Indeed, as the opening quotation reveals, this very question was already posed by Stigler in 1968.

A related question concerns the effect of price fixing on quality and welfare. One may argue that a high fixed price gives firms an incentive to provide higher quality, which may ultimately benefit consumers.

This chapter examines a model in which consumers search for a product, and firms exert consumer-specific effort to try to secure a sale to a consumer that has entered their store. Each consumer has firm-specific matching values, which reflect the extent to which this consumer likes the products that a firm has on offer. These matching values are unobservable to firms, and only observable to a consumer after it has visited a firm. Firms may form a price fixing cartel, but are not able to collude on effort.

As an example, consider a home-owner who wishes her bathroom to be resty-

[1] As an aside, cartels do exist that make a quality-fixing agreement, but compete in prices. Consider, for example, the Sugar Institute. This cartel of American sugar-refining firms, that operated between 1927 and 1936, did not make price agreements, but instead forced its members to obey extensive quality regulations, see Genesove and Mullin (2001). A quality-fixing cartel in the context of the model in this chapter would simply exert zero effort because raising effort only increases the costs for the winning firm, without increasing the probability of a sale.

led.[2] She may ask a specialized firm to propose a design, tailored to her specific needs and desires. The attractiveness of the offer will in part depend on how well the design matches the taste of the home-owner, something that is unobservable for the firm. It will also depend on the amount of effort that the firm exerts. Higher effort implies higher quality. Upon learning the price and details of the offer, the home-owner is free to contract with the current firm, to contact another firm, or to quit being active in this market altogether. In the last two cases, the firm incurs a loss, because the costs of preparing the offer is buyer-specific and cannot be recouped. The general features of this market (a buyer searches for potential sellers and sellers exert buyer-specific effort) are shared by many real-world markets. This chapter studies price fixing in such markets.

The analysis reveals that price fixing does allow firms to increase profits. However, the ability to raise profits is partially offset by an increase in competition along the quality dimension. Price fixing may indeed lead to higher quality. Unfortunately, both consumer welfare and social welfare are lower if firms are allowed to fix prices. Most surprisingly, collusion may yield prices that are *lower* than the competitive price. The intuition is that, by setting a low price, the cartel effectively discourages competition in costly effort.

Admittedly, the model in this chapter is not the first that studies a case in which firms can collude in one dimension, but have to compete in another. Stigler (1968) studies a perfectly competitive industry with persuasive advertising, where firms can either collude on prices or on advertising levels. He shows that, in the context of his model, any benefits from price fixing are competed away provided that there are constant returns to scale.

Jehiel (1992) and Friedman and Thisse (1993) consider collusion in a duopoly model with horizontal product differentiation á la Hotelling. They find that if firms first choose their locations non-cooperatively, and then collude in prices, the equilibrium features minimum product differentiation. Fershtman and Gandal (1994) and Brod and Shivakumar (1999) analyze how collusion in the product market affects profits in a model of R&D along the lines of d'Aspremont and Jacquemin (1988). They show that if firms decide non-cooperatively on R&D investments, and then expect to collude in the product market, profits may be even *lower* than if they act non-cooperatively in both stages. This depends on the size of the technological spillovers.

These papers have in common that firms first choose some investment before

[2] This example is due to Wolinsky (2005).

they compete on the product market. Current investments then become a bargaining chip in future cartel negotiations. The analysis in this chapter is not focused on such bargaining. In the model presented below, firms first choose collusive prices, and only then decide on some quality aspects of their product. This set-up captures more naturally the issue that seems most interesting: how does a market operate where, after having fixed prices, firms are still able to compete on other dimensions. The only paper that also assumes this timing of events is Fox (1994). Her main finding is that the level of advertising increases in the collusive price. However, her model does not easily lend itself for a welfare analysis, as she focuses on persuasive advertising. Additionally, she does not study the effects of semicollusion on prices.

The remainder of this chapter is structured as follows. Section 4.2 introduces the model. In section 4.3 the model is solved for the case that firms compete in all dimensions, while section 4.4 studies the equilibrium with price fixing. Section 4.5 examines the welfare effects of price fixing behavior. Section 4.6 presents an extension of the model in which industry demand is inelastic. Some brief conclusions are offered in 4.7.

4.2 The model

The benchmark model is based on Anderson and Renault (1999) and Wolinsky (2005). Anderson and Renault (1999) show that a generalized version of Perloff and Salop's (1985) model nests several well-known standard models such as the Diamond search model, monopolistic competition and Bertrand competition. Despite this generality, the model still yields analytic solutions and allows a direct comparison of the non-cooperative and collusive prices.

In the model, a finite number of firms compete by announcing prices and exerting buyer-specific effort. Buyers enjoy a firm-specific matching value, that is a priori unknown to both the firm and the buyer. More specifically, the model is as follows.[3]

4.2.1 Buyers

There is a continuum of buyers with a measure normalized to one. Each buyer has unit demand (*e.g.* a bathroom) and may approach a firm at cost $s > 0$. These costs

[3] The main difference with Wolinsky (2005) is the assumption of a finite number of firms. This allows a comparative statics exercise with respect to the number of firms. Anderson and Renault (1999) do not allow for endogenous quality, which excludes the possibility of semicollusion.

include the costs of finding a firm and the costs of transferring detailed information about her demand. If a buyer approaches a firm i, she learns the price p_i of the good, and her total valuation for the product of the firm, which equals $v + e_i + u_i$. Here, $v > 0$ is the intrinsic utility the buyer derives from obtaining the product, e_i is the buyer-specific effort exerted by the firm, and u_i is the matching value between the buyer and the firm. It is assumed that v is sufficiently large so as to guarantee that buyers will always obtain the good.[4] The matching value u_i is a random draw, IID across firms and buyers, from a cumulative density function F, which has support $[0, 1]$. For convenience, it is also supposed that F is twice differentiable and has positive marginal probability on its domain. The value u_i is only observable to buyers, and only after she has visited firm i. To guarantee that buyers have a positive reservation value, it is assumed that $s < \int_0^1 udF(u)$.

After any visit to a firm, a buyer may grant the project to a firm from which she has received an offer, or search for another firm. Her payoff if she buys from firm i after $k \geq 1$ visits is given by $U(e_i, u_i, p_i, k) = v + e_i + u_i - p_i - ks$. A buyer is allowed to come back to a previously visited firm at zero costs. It is assumed that the firm commits to a price once it is announced.

Consumers are assumed to search sequentially, which implies that buyers do not commit in advance to the number of searches. The optimal strategy for a buyer is thus some stopping rule that indicates that she should stop searching once she has found an offer that gives her net utility of at least $\hat{x}$, where $\hat{x}$ is to be determined endogenously.

4.2.2 Firms

There are n firms. For ease of exposition, the marginal costs of production are equal to zero for all firms. If a firm is not contacted by the buyer, it obtains zero profits. If a firm i is approached by the buyer, it announces its price p_i and exerts effort e_i to formulate a plan. This effort may also include *e.g.* time to inform the consumer regarding all aspects of the product.

The cost of effort is given by the function $c(e_i)$. This function satisfies the standard regularity assumptions $c(0) = 0$, $c'(e_i) > 0$ for $e_i > 0$, $c'(0) = 0$ and $c''(e) \geq 0$. Additionally, $c(e)$ is such that the following technical condition $\frac{\partial}{\partial e} \frac{c'(e)}{c''(e)} > 0$ is met. Effectively, this condition requires that the marginal costs of effort are not

[4] In section 4.6, it is shown that the main results continue to hold when the demand curve is downward-sloping.

too convex.[5] It is always satisfied for any quadratic cost function, for instance.

Effort is sunk. Hence the profit of the firm conditional on being approached by the buyer is $p_i - c(e_i)$ if the buyer buys from this firm and $-c(e_i)$ if she does not. For simplicity, firms are not able to charge diagnosis costs, *i.e.* firms cannot charge buyers a price solely for formulating a plan. In a slightly different set-up, Wolinsky (2005) does allow for this possibility, but he finds that firms charge zero diagnosis costs in equilibrium because of Bertrand competition in diagnosis fees.

4.2.3 Timing

This chapter considers two scenarios as to how firms compete on this market. First, they may act purely non-cooperatively. Second, they may form a price fixing cartel. In that case, the cartel announces a collusive price that maximizes expected joint profit conditional on every firm adhering to the agreement. Firms still exert effort in a non-cooperative fashion.

In the non-cooperative benchmark, the timing of the model is as follows. First, the representative buyer decides whether to search. If so, she picks a firm at random. Upon being contacted, the firm announces price p_i and exerts effort level e_i. After having observed this offer, the buyer may decide to search another firm, buy from the current firm, or quit searching altogether.

In the price fixing model, the timing is as follows. First, the firms collectively decide which uniform price p to set. Second, the buyer decides whether to search. If so, she picks a firm at random. Upon being contacted, the firm sets effort level e_i and just as before the buyer may buy, visit more firms, or quit. For simplicity, assume that firms are patient enough for the cartel to be stable. Calculating the exact value of the discount rate for which this is satisfied would greatly complicate the analysis without adding much insight.

4.3 The non-cooperative benchmark

In this section, the Nash equilibrium for the case that firms non-cooperatively set both prices and efforts is derived. The focus is on the symmetric pure strategy Nash equilibrium that consists of price p^N and effort e^N. The analysis here largely follows Wolinsky (2005).

[5] Denote marginal costs of effort as $m(e) \equiv c'(e)$. The condition then requires that $(m'm' - mm'')/m'm' > 0$, or $m'' < m'm'/m$. With $m' \geq 0$ and $m > 0$, this implies that m'' should not be too high, hence that marginal costs should not be too convex.

4.3.1 The search rule

Suppose that the buyer has not yet approached all n firms and that her current best option yields utility $v + e_i + u_i - p_i$. In the Nash equilibrium, a visit to a new firm j yields $v + e^N + E[u_j] - p^N$. The consumer prefers firm j over firm i if

$$u_j > p^N - p_i - e^N + e_i + u_i \equiv x.$$

Therefore, the expected benefit of one more search is $\int_x^1 (u - x) f(u) du$. Such a search is worthwhile if and only if these benefits exceed the costs on one more search, s. Thus, the buyer is exactly indifferent between searching and stopping if $x \geq \hat{x}$, with $\hat{x}$ implicitly defined by

$$\int_{\hat{x}}^1 (u - \hat{x}) f(u) du = s. \tag{4.1}$$

Hence, the buyer stops searching as soon as the current best offer is such that $x > \hat{x}$, where $\hat{x}$ is the unique solution to $g(\hat{x}) = s$. In the event that the buyer approached all n firms, it is clearly optimal for her to return to the firm that offered her the best offer.

4.3.2 Equilibrium effort and price

Consider the decision of firm i. Suppose that all other firms charge p^N and set effort level e^N. In the following, the best reply of firm i is derived, which in turn allows one to derive the equilibrium values p^N and e^N.

The probability that the buyer samples firm i is given by

$$Pr\{\text{firm } i \text{ is sampled}\} = \frac{1}{n} + \frac{F(\hat{x})}{n} + \frac{F(\hat{x})^2}{n} + \ldots + \frac{F(\hat{x})^{n-1}}{n},$$

which simplifies to

$$Pr\{\text{firm } i \text{ is sampled}\} = \frac{1}{n} \cdot \frac{1 - F(\hat{x})^n}{1 - F(\hat{x})}.$$

as $F(\hat{x}) \in (0, 1)$.

The probability that the buyer *stops* at firm i (*i.e.* makes an immediate purchase), given that firm i is sampled, is equal to $Pr(x > \hat{x})$, or

$$Pr(e_i - e^N + p^N - p_i + u_i > \hat{x}) = Pr(u_i - \Delta > \hat{x}) = 1 - F(\hat{x} + \Delta),$$

where $\Delta \equiv p_i - p^N - e_i + e^N$. The buyer *returns* to firm i after having visited all firms if $\max_{j \neq i}\{u_j\} < u_i - \Delta$, which occurs with probability $\int_0^{\hat{x}+\Delta} F(u-\Delta)^{n-1} f(u)\, du$.

Combining these elements, the expected profits of firm i, conditionally on being sampled, are given by

$$\pi(\Delta) = p_i \left[1 - F(\hat{x}+\Delta) + n\frac{1-F(\hat{x})}{1-F(\hat{x})^n}\int_0^{\hat{x}+\Delta} F(u-\Delta)^{n-1} f(u)du\right] - c(e_i).$$

Following Anderson and Renault (1999), the profit function is assumed to be concave. Straightforward calculations show that

Proposition 4.1. *The unique symmetric equilibrium has*

$$p^N = \frac{1}{\frac{1-F(\hat{x})^n}{1-F(\hat{x})} f(\hat{x}) - n\int_0^{\hat{x}} F(u)^{n-1} f'(u)du}, \tag{4.2}$$

$$c'(e^N) = \frac{1-F(\hat{x})}{1-F(\hat{x})^n}. \tag{4.3}$$

The buyer searches until she encounters a firm i with $p^N - p_i - e^N + e_i + u_i > \hat{x}$, *with* $\hat{x}$ *given by (4.1), or until she has visited all firms. In the latter case, she buys from the firm that offers her the highest net utility.*

Proof. The expressions follow directly from solving the first-order conditions and imposing symmetry. Existence and uniqueness then follows from the concavity of the profit function and convexity of the feasible set. ■

The equilibrium price p^N coincides with Anderson and Renault's (1999) result. This should not come as a surprise. Given that effort is set optimally, firms in this model face the exact same decision problem regarding price as the firms in their model do. The comparative statics are as follows:

Proposition 4.2. *If* $1 - F(x)$ *is log-concave on* $[0, 1]$, *then price* p^N *is (i) increasing in search costs s and (ii) decreasing in the number of firms n. Furthermore, effort* e^N *is (iii) increasing in s and (iv) decreasing in n.*

Proof. Part (i) and (ii) follow directly from Anderson and Renault (1999). For (iii), first note from (4.1) that $\hat{x}$ is decreasing in s. Hence, to show that e^N is decreasing in s, it is sufficient to establish that $\frac{\partial}{\partial \hat{x}}\left(\frac{1-F(\hat{x})}{1-F(\hat{x})^n}\right) < 0$. This derivative equals

$$\frac{\partial}{\partial \hat{x}}\left(\frac{1-F(\hat{x})}{1-F(\hat{x})^n}\right) = \frac{f(\hat{x})\left[nF(\hat{x})^n - F(\hat{x}) - (n-1)F(\hat{x})^{n+1}\right]}{F(\hat{x})(1-F(\hat{x})^n)^2}.$$

Its sign is strictly negative if $nF(\hat{x})^{n-1} - (n-1)F(\hat{x})^n < 1$, which clearly holds for $n = 2$. Now suppose it holds for some $n > 1$. Then it will also hold for $n+1$ if $nF(\hat{x})^n - (n-1)F(\hat{x})^{n+1} > (n+1)F(\hat{x})^{n+1} - nF(\hat{x})^{n+2}$. This inequality can be reduced to $F(\hat{x})^2 - 2F(\hat{x}) + 1 > 0$, which is satisfied for all $F(\hat{x}) \in (0,1)$. Hence, by induction, the result follows. Finally, to derive result (iv), note that

$$\frac{\partial}{\partial n}\left(\frac{1-F(\hat{x})}{1-F(\hat{x})^n}\right) = \frac{(1-F(\hat{x}))F(\hat{x})^n \ln(F(\hat{x}))}{(1-F(\hat{x})^n)^2}.$$

which is strictly negative, as $\ln(F(\hat{x})) < 0$. ■

Proposition 4.2 shows that the equilibrium properties of the model are intuitive. For well-behaved distribution functions, equilibrium price and effort are decreasing in the number of firms. As competition intensifies, firms lower their price to attract the buyer. At the same time, firms exert less effort as the probability that the buyer eventually buys at a given firm decreases. As search costs increase, firm effectively have more market power once they are visited by a consumer. This allows them to set a higher price. At the same time, firms exert more effort as the probability that the buyer eventually buys at a given firm increases.

4.4 The price fixing outcome

Under price fixing, each cartel member has agreed to post a fixed price, but is free to compete as vigorously in effort as it pleases.

The profit-maximizing cartel price p^* can be derived as follows. Given that it is finite (this is confirmed below), the assumption that the market is covered implies that the probability that the buyer will ultimately obtain the good is equal to 1. The expected total cost for the cartel is the expected sum of effort, which is $\sum_{i=0}^{n-1} c(e)F(\hat{x})^i$. Hence, the problem of the cartel is to set a price p^* as to maximize

$$\Pi = p^* - c(e^*(p)) \cdot \frac{1-F(\hat{x})^n}{1-F(\hat{x})}.$$

Effort $e^*(p)$ is implicitly defined by the first-order condition for individual firm optimality. Thus, the cartel explicitly takes the effect of the fixed cartel price on the firms' equilibrium effort into account. Under the assumption that all other firms set $e^*(p)$, the analysis below derives the best reply of one firm, which enables a derivation of $e^*(p)$. It will be convenient to work with a short-hand expression of per-firm profit:

$$\pi(\Delta) = p^* H(\Delta) - c(e_i).$$

where

$$H(\Delta) \equiv 1 - F(\hat{x} + \Delta) + n \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n} \int_0^{\hat{x}+\Delta} F(u - \Delta)^{n-1} f(u) du.$$

is the probability that the buyer obtains the good from firm i, conditional on firm i being sampled by the buyer. Now, per-firm effort can be written as

$$c'(e) = p^* h_{e_i}|_{\Delta=0}. \tag{4.4}$$

where $h_{e_i}|_{\Delta=0}$ denotes the partial derivative of $H(\Delta)$ with respect to e_i, evaluated in $\Delta = 0$. This marginal probability of sale is evaluated in $\Delta = 0$ as in equilibrium all firms charge the same (collusive) price and provide the same level of effort. For notational convenience, this is simply written as h_e.

Equation (4.4) implicitly defines effort as a function of price. Totally differentiating, one obtains that

Lemma 4.1. *Under semicollusion, equilibrium effort $e^*(p)$ is an increasing function of price;*

$$e'(p) = \frac{h_e}{c''(e)} > 0. \tag{4.5}$$

Proof. Recall that $c''(e_i) > 0$. Therefore, it is sufficient to show that the marginal probability of sale $h_e > 0$. Observe that

$$\begin{aligned} h_e &= f(\hat{x}) + \frac{n\left[1 - F(\hat{x})\right]\left[(n-1)\int_0^{\hat{x}} F(u)^{n-2} f(u)^2 du - F(\hat{x})^{n-1} f(\hat{x})\right]}{1 - F(\hat{x})^n} \\ &= f(\hat{x}) - \frac{n\left[1 - F(\hat{x})\right]\left[\int_0^{\hat{x}} F(u)^{n-1} f'(u) du\right]}{1 - F(\hat{x})^n}. \end{aligned} \tag{4.6}$$

From 4.2, this implies that

$$h_e = \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n} \frac{1}{p^N} > 0. \tag{4.7}$$

■

Lemma 4.1 is intuitive; as a firm increases its effort, it increases the probability that it trades with the buyer. Therefore, as price increases, individual firms try to win the contract by exerting more effort. A bigger trophy results in more effort. Assuming that Π is concave,[6] it can now be shown that:

Proposition 4.3. *With price fixing, the optimal cartel price is*

$$p^* = \frac{c''(e^*)}{h_e^2} \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n}.$$

The effort exerted by each firm in the cartel is given by

$$c'(e^*) = \frac{c''(e^*)}{h_e} \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n}.$$

Proof. Given concavity of Π, the sufficient condition for the unique optimal price p^* is $\frac{\partial \Pi}{\partial p} = 0$, or

$$\frac{\partial \Pi}{\partial p} = 1 - c'(e) \cdot e'(p) \cdot \frac{1 - F(\hat{x})^n}{1 - F(\hat{x})}.$$

This derivative can be simplified by inserting the expressions for $c'(e)$ and $e'(p)$ in (4.4) and lemma 4.1. Rewriting gives p^*.

The level of effort exerted by each firm in the cartel is found by substituting the expression for p^* into equation (4.4). Given that the regularity condition $\frac{\partial}{\partial e} \frac{c'(e)}{c''(e)} > 0$ is satisfied, a unique positive solution to this equation exists. ■

The cartel sets a fixed price p^*, taking the opportunistic behavior of its own members into account. Agreeing to post a very high collusive price is not in the cartel's interest. When firms have a strong incentive to compete along the effort dimension, the cartel's profit may be competed away through vigorous competition in effort. Therefore, it is sometimes optimal for the colluding firms to set a relatively low price, as the following result shows.

Corollary 4.1. *The optimal cartel price p^* is lower than the Nash equilibrium price p^N if and only if*

$$c''(e^*) < h_e.$$

[6] A sufficient condition for concavity of Π is $c'''(e) < 0$.

Proof. The Nash price p^N is strictly higher than the collusive price p^* if and only if

$$\frac{1}{\frac{1-F(\hat{x})^n}{1-F(\hat{x})} f(\hat{x}) - n\int_0^{\hat{x}} F(u)^{n-1} f'(u)du} > \frac{c''(e^*)}{h_e^2} \frac{1-F(\hat{x})}{1-F(\hat{x})^n}.$$

This is equivalent to

$$-\frac{H}{h_p} > \frac{c''(e^*)}{h_e^2} \frac{1-F(\hat{x})}{1-F(\hat{x})^n}.$$

Note that $h_p = -h_e$: a unit decrease in effort has the same effect on the probability that the firm is selected by the buyer as a unit increase in price. This allows one to simplify the above inequality to

$$c''(e^*) < \frac{1-F(\hat{x})^n}{1-F(\hat{x})} \cdot H \cdot h_e. \tag{4.8}$$

If all firms charge the same price and provide the same level of effort, $H = \frac{1-F(\hat{x})}{1-F(\hat{x})^n}$, and therefore a collusive firm charges a lower price (and exerts less effort) than a non-cooperative firm if

$$c''(e^*) < h_e.$$

■

Thus, if the costs of effort respond sluggishly to an increase in effort (*i.e.* $c''(e)$ is sufficiently small), the cartel chooses to set a low price in order to prevent a costly war in effort between the firms. For instance, if the cost of effort function is given by $c(e) = ce^2$ and the matching value is drawn from the uniform distribution, a cartel agrees on a price below the competitive price if $c < 1/2$.[7]

Corollary 4.1 can be considered to be the main result of this chapter. The result admits at least two interpretations. First, given that price fixing adequately describes actual collusive behavior, antitrust authorities should also investigate industries with 'suspicious' low prices. Those industries keep prices low in order to forestall fierce competition in effort. Another interpretation is that collusion is often not a very profitable strategy, as the collusive price is close to the non-cooperative price. Only if competition along the effort dimension is sufficiently costly, firms may be willing to form a cartel.

[7] Note that concavity of Π, and hence an equilibrium in pure strategies, requires $c > 1/4$.

With price fixing, the following comparative statics can be derived:

Proposition 4.4. *If $1 - F(x)$ is log-concave on $[0,1]$, then effort increases in search costs. Furthermore, if $f'(x) \geq 0 \; \forall x$, price increases in search costs as well. If additionally $n > 1/(1 - F(\hat{x}))$, price and effort decrease in the number of firms.*

Proof. As $\hat{x}$ decreases in s, it is sufficient to show that effort decreases in $\hat{x}$ to prove that effort increases in s. Note that e^* is uniquely determined by $\frac{c''(e)}{c'(e)} = h_e \frac{1-F(\hat{x})^n}{1-F(\hat{x})} = 1/p^N$, using (4.7). As $\frac{c''(e)}{c'(e)}$ decreases in e, e^* increases in s if $1/p^N$ decreases in $\hat{x}$ and, from proposition 4.2, this is known to be true.

To demonstrate that price increases in search costs, note that p^* can be written as $p^* = \frac{c'(e^*)}{h_e}$. As e^* is increasing in s, it is sufficient to have h_e non-increasing in s, and thus to have h_e non-decreasing in $\hat{x}$. This is true if and only if

$$f'(\hat{x})(1 - F(\hat{x})^n) + nf(\hat{x}) \int_0^{\hat{x}} F(u)^{n-1} f'(u) du \geq 0,$$

This is clearly satisfied if $f' \geq 0$.

For the effect of n, first derive the conditions under which effort decreases in the number of firms. This holds if the RHS of

$$\frac{c''(e^*)}{c'(e^*)} = h_e \frac{1 - F(\hat{x})^n}{1 - F(\hat{x})}$$

increases in n. Using (4.6), this is the case if

$$\begin{aligned} f(\hat{x}) \left(\frac{1 - F(\hat{x})^n}{1 - F(\hat{x})} \right) \quad & - \quad n \int_0^{\hat{x}} F(u)^{n-1} f'(u) du \\ & > \quad f(\hat{x}) \left(\frac{1 - F(\hat{x})^{n-1}}{1 - F(\hat{x})} \right) - (n-1) \int_0^{\hat{x}} F(u)^{n-2} f'(u) du \end{aligned}$$

or

$$F(\hat{x})^{n-1} f(\hat{x}) + \int_0^{\hat{x}} F(u)^{n-2} f'(u)(n - 1 - nF(u)) du > 0.$$

Clearly, the inequality holds if $f' \geq 0$ and $n > 1/(1 - F(\hat{x}))$.

Now, examine the effect of an increase in n on the collusive price. Note from (4.3) that one can write

$$p^*(n) = \frac{c'(e^*(n))}{h_e(n)}.$$

The equilibrium price is decreasing in n iff $p^*(n) < p^*(n-1)$, which holds if

$$\frac{c'(e^*(n))}{h_e(n)} < \frac{c'(e^*(n-1))}{h_e(n-1)}.$$

From concavity of c and given that $f' \geq 0$ and $n > 1/(1-F(\hat{x}))$, follows the condition that $c'(e^*(n)) > c'(e^*(n-1))$. Sufficient for the inequality to be satisfied then is $h_e(n) > h_e(n-1)$. Using (4.6), this is the case if

$$\int_0^{\hat{x}} F(u)^{n-2} f'(u) \left[(n-1)\left(1-F(\hat{x})^n\right) - n\left(1-F(\hat{x})^{n-1}\right)F(u)\right] du > 0$$

As $f' \geq 0$, sufficient for this to hold is

$$(n-1)\left(1-F(\hat{x})^n\right) - n\left(1-F(\hat{x})^{n-1}\right)F(\hat{x}) > 0,$$

which simplifies to $n\left(1-F(\hat{x})\right) - 1 + F(\hat{x})^n > 0$, which is satisfied for $n > 1/(1-F(\hat{x}))$. ■

The sufficient conditions for monotone comparative statics under price fixing are stronger than under non-cooperative behavior. Under non-cooperative behavior, log-concavity guarantees that the competitive price and quality decrease in the number of firms. This result no longer holds in the presence of a price fixing cartel. A possible explanation is the following. An increase in the number of firms has two opposite effects. On the one hand, it intensifies competition between firms. For a given price, this gives them a stronger incentive to compete in the quality dimension, which induces the cartel to charge a lower price. On the other hand, an increase in the number of firms increases the expected matching value of the consumer. This increases the market power of the cartel, and allows it to charge a higher price and hence the cartel members to offer a higher quality. For some distribution functions, the latter effect could outweigh the first effect. However, note that the conditions derived in proposition 4.4 are merely sufficient conditions. The monotone comparative statics are expected to hold for a wider range of parameters.

4.5 Social welfare

This section studies the welfare effects of price fixing. The natural measure of social welfare W is the sum of expected buyer's utility and expected industry profit.

Formally,

$$W = E[v + e + u - k(c(e) + s)].$$

Using the facts that $s \equiv \int_{\hat{x}}^{1} (u - \hat{x}) f(u) du$ and the expected number of visits $E[k]$ equals $\frac{1-F(\hat{x})^n}{1-F(\hat{x})}$, welfare boils down to

$$W = v + e - \frac{1 - F(\hat{x})^n}{1 - F(\hat{x})} \cdot c(e) + \hat{x}\,[1 - F(\hat{x})^n] + \int_0^{\hat{x}} u dF(u)^n.$$

Since the third and fourth terms of this expression are independent of effort, a social planner who can dictate effort would set effort e^W such that

$$c'(e^W) = \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n} = c'(e^N).$$

Hence, the socially optimal level of effort equals the level of effort under Nash play. This is a notable result in itself. Wolinsky (2005) finds that, as buyers do not fully bear the costs of search themselves, they visit too many firms in equilibrium. This leads to an inefficient level of effort, as compared to the first-best social welfare optimum. This result shows that, if the social planner is unable to meddle with the buyer's search strategy, social welfare under non-cooperative play is optimal in a second-best sense.

The finding that in the competitive mode effort is set (second-best) optimally implies that a price fixing industry always reduces social welfare, as

$$c'(e^*) = \frac{c''(e^*)}{h_{e_i}} \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n} \neq \frac{1 - F(\hat{x})}{1 - F(\hat{x})^n} = c'(e^W).$$

Thus, effort is distorted away from the optimal competitive level. Moreover, the search strategy of the buyer is invariant under both modes of competition and therefore price fixing firms necessarily yield lower welfare levels than non-cooperative firms. By construction, firms must be better off if they choose to set a price $p^* \neq p^N$. With total welfare decreasing, and firm profits increasing, consumers are necessarily worse off. The welfare effects of price fixing in our model can thus be summarized as follows:

Proposition 4.5. *Regardless of its effect on price, price fixing is bad for welfare and bad for consumers. Firms are better off if they can fix prices.*

Returning to the question of Stigler (1968) it is clear that firms are strictly better off with price fixing than they are when competing in prices: the cartel can still choose to fix prices at the competitive level p^N. The fact that it chooses not to do so implies that firms are strictly better off under price fixing.[8] It is also clear that firms could do even better under full collusion, *i.e.* if they were also able to collude on effort. Thus, in the words of Stigler, the monopoly profit achieved by suppressing price competition will be lowered, but not be eliminated by non-price competition.

4.6 Elastic demand

Though the model is quite general, it does assume that buyers always buy. This implies that prices are just a transfer from buyers to firms and greatly simplifies the welfare analysis. However, one may worry that the assumption of inelastic demand is driving the welfare results. To investigate this issue, adjust the model in the following direction. Buyers still have unit demand, but buy if and only if the most attractive offer yields at least a positive utility. That is, $v + u_i + e_i - p_i > 0$ is required to hold if the buyer selects firm i. This introduces a downward-sloping demand curve, as the fraction of buyers who purchase good i decreases in $p_i - e_i$. For convenience, normalize v to zero and suppose that buyers do not face search costs.

As before, suppose that a symmetric equilibrium exists where firms exert effort e^N and charge a price p^N. To characterize the equilibrium, suppose first that $e^N - p^N \geq 0$ and firm i deviates from the proposed equilibrium. A consumer buys from firm i if two conditions hold. First, firm i should offer more utility than any other firm: $u_i + e_i - p_i > \max\{u_{-i}\} + e^N - p^N$, or $u_i - \Delta > z$, where $\Delta \equiv p_i - p^N - e_i + e^N$ and $\max\{u_{-i}\} \equiv z$. Second, firm i should offer positive utility and this requires $u_i > p_i - e_i$. Firm i chooses e_i and p_i as to maximize

$$\pi(\Delta) = p_i \int_{p_i - e_i}^{1} F(u - \Delta)^{n-1} f(u) du - c(e_i).$$

Unfortunately, there is no general closed-form solution to this maximization problem. Without an expression for p^N in closed-form, one cannot compare it with the collusive price. To circumvent this problem, assume that u is uniformly distributed, $n = 2$, and $c(e) = ce^2$. Then, in the non-cooperative equilibrium,

$$e^N = \frac{1}{2c + \sqrt{1 + 4c(2c - 1)}},$$

[8] Except, that is, in the knife-edge case $c''(e^*) = h_e$ where there is no effect of semicollusion on welfare.

$$p^N = \frac{2c}{2c + \sqrt{1 + 4c(2c-1)}}.$$

It can be verified that this solution is valid only for $c \geq \frac{1}{2}$. For c below $\frac{1}{2}$, $p^N - e^N < 0$ and the constraint that the firm should offer a positive payoff no longer binds. In this case, the relevant profit function of a firm that contemplates to deviate from the symmetric equilibrium is

$$\pi(\Delta) = p_i \int_0^1 F(u - \Delta)^{n-1} f(u) du - c(e_i).$$

For the special case of a uniform distribution and quadratic costs, the optimal effort and price are

$$e^N = \frac{1}{4c},$$
$$p^N = \frac{1}{2}.$$

In both cases, effort is given by $\frac{p}{2c}$. Hence, under the price fixing regime, the cartel maximizes

$$\Pi = \Pr\{\text{sale}\} p - 2ce^2,$$

subject to the constraint $e = \frac{p}{2c}$. The optimal collusive price is

$$p^* = \begin{cases} c & \text{if } c \in \left[\frac{1}{4}, \frac{1}{2}\right), \\ \frac{2c}{1+2\sqrt{1+3c(c-1)}} & \text{if } c \geq \frac{1}{2}. \end{cases}$$

Clearly, $p^N > p^*$ if $c \in [\frac{1}{4}, \frac{1}{2}]$. So, even with downward-sloping demand, the collusive price may be below the non-cooperative price. Finally, it is easy to show that welfare under price fixing is strictly below welfare under non-cooperative behavior, unless $c = \frac{1}{2}$, in which case welfare is unchanged.

4.7 Concluding remarks

In the real world, fully collusive industries in which all firms can collude on every single aspect of their product, are hard if not impossible to find. This chapter explored the effects of a price fixing agreement in a model with vertical product differentiation and sequential search. In a model that builds on Anderson and Renault

(1999) and Wolinsky (2005), it was showed that if firms collude in prices but not in effort, they may prefer to set prices below the competitive price to avoid a costly war in effort. Still, social welfare is always lower in the case of price fixing. Firms are strictly better off with price fixing.

These results have important implications for antitrust policy. To find evidence of collusion, antitrust authorities tend to look for industries where prices are relatively high. The analysis in this chapter suggests that in industries where firms can collude on prices but not on other aspects of their product, prices may actually be lower than competitive prices. An alternative interpretation is that a cartel is not very profitable if firms can easily evade the collusive agreement by competing in effort. Finally, a change from non-cooperative behavior to semicollusive behavior induces a change in product design. Antitrust authorities should take this into account when calculating the 'but for' price to determine the damages of collusion.

As a suggestion for future research, it would be very interesting to study collusion in a dynamic framework. This may help to understand why many cartels restrict themselves to fixing prices.

Chapter 5

The anti-collusive effect of resale price maintenance

> The manufacturers' interests seem to be best served when distributors resell their products under such competitive conditions as may exist at the level of distribution and at the lowest prices resulting from that competition.
>
> Lester G. Telser (1960, p. 86)

5.1 Introduction

This chapter revisits the topic of resale price maintenance (RPM), which is perhaps one of the oldest problems in the industrial organization literature. When an upstream firm engages in RPM, he limits the degree of freedom of downstream firms have in setting prices. An RPM agreement may prevent a downstream to charge below a certain threshold (a price floor), above a threshold (a price ceiling), or a combination of both. This chapter focuses on minimum RPM, or a price floor, which seems to be the most common form of RPM.[1] The practice of RPM is puzzling. As Telser (1960) observed, there seems to be no good explanation for a manufacturer to constrain price competition among retailers, as high prices reduce final demand.

The literature offers three types of explanations.[2] First, RPM may be used as

[1] Ippolito (1991), Table 2, reports that between 1976 and 1982 about 95% of the antitrust cases with a resale price maintenance charge involved minimum RPM. Throughout this chapter, the concepts of RPM and price floor are used interchangeably.

[2] See Mathewson and Winter (1998) or Rey and Vergé (2003) for recent surveys.

part of a cartel between manufacturers (Jullien and Rey, 2007). The idea is that RPM reduces downstream price variation, and this helps to detect cartel deviations. Second, RPM could be used to maintain a cartel between retailers. In this scenario retailers force the manufacturer to impose and maintain a price floor. Third, RPM can be viewed as a method to induce retailers to provide the optimal level of services (Telser, 1960).

This chapter advances a different theory. Resale price maintenance, in the form of a price floor, enables the manufacturer to prevent the emergence of tacit collusion between retailers. The argument is relatively simple. When firms repeatedly interact, they may be able to coordinate on a collusive, but non-cooperative, equilibrium. In this equilibrium each firm sets the joint profit maximizing price in every period. A firm is willing to do this because he believes, correctly, that if he undercuts the monopoly price, all other firms lower their prices in the subsequent periods. Thus, collusion is sustained by a threat to punish a deviation. This strategy of tacit collusion does not work when firms are relatively impatient. In that case, they value the present profits from deviating from the cartel agreement higher than the delayed loss in profits as a result of the punishment. The discount factor for which firms are exactly indifferent between deviating from and complying with the cartel agreement is called the critical discount factor. If a variable, such as the number of firms, affects the critical discount factor, it affects the stability of a cartel. A price floor has an effect on the critical discount factor as well. By imposing a price floor, the manufacturer increases the non-cooperative profits a retailer earns in the punishment phase. This increases the critical discount factor, because higher non-cooperative retailer profits reduces the punishment for deviation.

The analysis below formalizes this intuition in the canonical model of a monopolistic manufacturer and two retailers. The key difference between the framework in this chapter and most of the theoretical literature is that this chapter studies RPM in an infinitely repeated game, whereas the literature typically restricts the analysis to a one-shot game. Notable exceptions are Jullien and Rey (2007) and Rey and Vergé (2008).

Although this alternative, anti-collusive interpretation of RPM seems counterintuitive at first, it is consistent with some salient features of RPM. According to many observers, the pro-collusive interpretation of RPM is generally invalid. Ippolito (1991) examines U.S. antitrust cases between 1976 and 1982, in which firms were alleged of engaging in (the illegal act of) RPM. She concludes that there is little evidence to support the hypothesis that RPM is used to maintain collusion. Cooper, Froeb, O'Brien and Vita (2005) summarize the empirical research on vertical restraints and reach the same conclusion.

Telser's (1960) service provision theory, and its variants, seems to better fit Ippolito's (1991) data. However, service provision cannot explain the existence of price floors on markets for relatively simple goods, such as refined sugar, beer, milk or candy.

These observations necessitate an alternative explanation for the use of RPM for simple goods. The theory in this chapter explains the existence of price floors for such products. In the suggested model, it is perfectly rational for a manufacturer to impose a price floor. The model also explains a remarkable empirical stylized fact. According to Overstreet (1983), prices in "traditional stores" fall after a price floor is imposed. Exactly this is predicted by the model below.

Additionally, Dufwenberg, Gneezy, Goeree and Nagel (2007) obtain, in a laboratory experiment, results that are predicted by the analysis in this chapter. Dufwenberg *et al.* (2007) consider the effect of an increase in the price floor on the pricing behavior of subjects in a Bertrand game. They find that, on average, the lowest (market) price decreases as the price floor increases with two competitors. The opposite holds for sessions with four competitors. Hence, an increase of the price floor tends to decrease prices but only if collusion was stable before the treatment.

Before presenting the formal model, it may be appropriate to briefly summarize the current legal status of RPM. Traditionally, RPM is subject to a much more stringent treatment than other, sometimes outcome-equivalent, vertical restraints such as exclusive dealing or tie-ins. The European Commission views price floors generally as anti-competitive.[3] In the United States, RPM is considered as illegal since *Dr. Miles*[4] in 1911. Last year, however, the Supreme Court overruled this position in *Leegin*[5] and RPM is now subject to a rule of reason. The next section introduces the formal model. Sections 5.2.2 and 5.2.3 develop the main result of this chapter, namely that price floors may have an anti-collusive effect. It is shown that this result extends to competition with differentiated products in section 5.2.4. Section 5.3 concludes.

[3] The Commission's position is further explained in *Guidelines on Vertical Restraints*, Official Journal of the European Communities, October 13, 2000.

[4] *Dr. Miles Medical Co.* v. *John D. Park and Sons Co.*, 220 U.S. 373 (1911).

[5] *Leegin Creative Leather Products, Inc.* v. *PSKS, Inc.*, 551 U.S. 480 (2007).

5.2 The model and analysis

5.2.1 Preliminaries

An upstream firm, the manufacturer, produces a good at zero marginal costs. The manufacturer sets a linear price c to maximize profits. The product is the sole input factor of two downstream firms, retailer 1 and 2. They produce a homogeneous good which is sold to the final consumers. The retailers compete by simultaneously announcing prices. Demand is given by $Q(p)$, where the market price p is the minimum of p_1 and p_2. Demand is equally split between retailers whenever $p_1 = p_2$. As is standard, market demand is decreasing in the market price, and there exists a unique $p^k(c) \geq 0$ which maximizes $(p-c)Q(p)$. The downstream firms may engage in tacit collusion and, if they elect to do so, they maintain cooperation through grim trigger strategies.

The timing of the game is as follows. First, the manufacturer announces the wholesale price c and, possibly, the price floor $f \geq c$. Subsequently, the two downstream firms observe c, which defines their common marginal costs, and may form a cartel. Then, the retailers interact an infinite number of times on the market stage. Time is discrete and firms use a common discount factor $\beta \in (0,1)$ to weigh future payoffs.

5.2.2 Equilibrium

The assumption of perfect substitutes implies that non-cooperative price competition yields the retailers zero profits. In the non-cooperative equilibrium, the retailers set their prices equal to marginal costs in every stage game. By colluding on the monopoly price, each retailer earns a stage profit of

$$\pi^k = \frac{1}{2}\left(p^k - c\right) Q\left(p^k\right).$$

The retailers may not be able to coordinate on the monopoly price. When it is more profitable for a cartel member to deviate from the agreement and undercut his fellow cartel member, collusion is unstable. An optimal deviation from the collusive agreement is to set $p^k - \epsilon$, with ϵ arbitrarily small but positive. The associated stage profits are

$$\pi^d = \left(p^k - c\right) Q\left(p^k\right).$$

With grim trigger strategies, defection is not profitable if

$$\frac{1}{2}\frac{1}{1-\beta}\left(p^k-c\right)Q\left(p^k\right) > \left(p^k-c\right)Q\left(p^k\right)$$

and this simplifies to

$$\beta > \frac{1}{2}.$$

So, the stability of the cartel, and therefore the likelihood that collusion emerges, is independent of c. In the first period, the manufacturer maximizes profits by setting c such that

$$Q\left(c\right) + cQ'\left(c\right) = 0 \tag{5.1}$$

if $\beta \leq \frac{1}{2}$. For this case, the manufacturer charges the monopoly price of the fully integrated structure, $p^k(0)$. Otherwise, he maximizes $cQ\left(p^k\left(c\right)\right)$. The corresponding first-order condition is

$$Q\left(p^k\right) + \frac{cQ'\left(p^k\right)^2}{\left(p^k-c\right)Q''\left(p^k\right)+2Q'\left(p^k\right)} = 0. \tag{5.2}$$

Hence, the manufacturer obtains the profits of the fully integrated vertical structure if the retailers are sufficiently impatient. When the retailers are patient, and form a cartel, the classic double marginalization problem arises, at the expense of the manufacturer.

5.2.3 A price floor

Now, suppose that the manufacturer is allowed to impose a price floor $f \geq c$. In a standard static game doing so would be irrational, because a profit-maximizing manufacturer wishes to maximize sales, given that everything else stays the same. Under a price floor, sales (and therefore the manufacturer's profit) would typically decrease. The simple message of this chapter is that 'everything else' does *not* stay the same when the manufacturer introduces a price floor. In a dynamic environment, a price floor may be profitable for the manufacturer, as it induces non-cooperative behavior from retailers who would otherwise form a cartel.

Under a price floor agreement, the retailers agree not to sell at a price below f. It is assumed that the manufacturer is capable of enforcing the contract.

Note first that the non-cooperative profits increase under a price floor. Retailers would charge f, which is strictly above marginal cost. The non-cooperative profits become

$$\pi^N = \frac{1}{2}(f - c)\, Q(f).$$

The collusive and defection profits are unaffected by the price floor. The optimal cartel price is still $p^k(c)$. Of course, this assumes that $p^k(c) > f$. A price floor above the cartel price can never be in the interest of the manufacturer. The condition for cartel stability changes to

$$\left(p^k - c\right) Q\left(p^k\right) + \frac{1}{2}\frac{\beta}{1-\beta}(f - c)\, Q(f) < \frac{1}{2}\frac{1}{1-\beta}\left(p^k - c\right) Q\left(p^k\right). \tag{5.3}$$

It is straightforward to show that for any $\beta \in (0,1)$, there exists an f such that the above inequality is violated (and collusion is infeasible). A profit-maximizing manufacturer would clearly impose a price floor when $\beta > 1/2$. To see this, fix c. Without a price floor, the retailers form a cartel (since they are sufficiently patient and collusion is profitable) and the manufacturer's profit is $cQ(p^k(c))$. By imposing the lowest $f \in \left(c, p^k\right)$ such that 5.3 is violated, collusion breaks down. The manufacturer's profit increases to $cQ(f)$. These observations imply the main result.

Proposition 5.1. *If $\beta \leq 1/2$, the retailers act non-cooperatively and set price equal to their marginal cost (the wholesale price c). The manufacturer chooses c such that $cQ(c)$ is maximized. If $\beta > 1/2$ the manufacturer induces non-cooperative behavior by imposing a price floor f. The retailers obtain a positive profit. The manufacturer selects f such that 5.3 holds with equality.*

A price floor enables the manufacturer to induce non-cooperative behavior among the downstream firms. The existing literature takes downstream behavior as given, and therefore concluded that a manufacturer cannot profitably impose a binding price floor.

5.2.4 Product differentiation

The above analysis assumes that the retailers produce perfect substitutes. This may be reasonable when retailers just serve as outlets of the manufacturer and do not add any value to the product. Typically, however, retailers do add value and differentiate themselves away from their rival's product. This section shows that the anti-collusion result can be easily extended to differentiated products. Suppose that the retailers produce imperfect substitutes and retailer i's demand is given by

$$q_i = \frac{1}{2}\left(1 - p_i\left(1 + \frac{d}{2}\right) + \frac{dp_j}{2}\right) \tag{5.4}$$

where $d \in [0, \infty)$, $i = 1, 2$ and $i \neq j$. This demand specification was proposed by Shubik (1980) and applied by, amongst others, Rothschild (1992) and Albæk and Lambertini (1998). The degree of substitution is captured by d. For $d = 0$, the firms offer independent products and are *de facto* monopolists. As d increases, the products become increasingly similar. It can be shown that (5.4) is a special case of Singh and Vives' (1984) specification.

The game is solved through backward induction. Suppose the manufacturer announces $c \geq 0$ in the first period. Then, if the retailers act non-cooperatively at each subsequent market stage, they charge

$$p^N = \frac{2 + 2c + cd}{4 + d} \tag{5.5}$$

in the symmetric equilibrium. The retailers are active if and only if $c \leq 1$, since they incur negative profits otherwise. Given non-cooperative behavior, the manufacturer maximizes

$$\pi_M^N = c\left(1 - \frac{2 + 2c + cd}{4 + d}\right) \tag{5.6}$$

with respect to c. At the optimum, the manufacturer sets $c = 1/2$. Then, the stage profits of the retailers and manufacturer become

$$\pi_R^N = \frac{2 + d}{4(4 + d)^2}, \qquad \pi_M^N = \frac{2 + d}{16 + 4d}. \tag{5.7}$$

When the retailers form a cartel, the optimal cartel price is given by $\frac{1+c}{2}$. Again, it is optimal for the manufacturer to set $c = 1/2$. The stage profits are $\pi_R^k = 1/32$ and $\pi_M^k = 1/8$. Remarkably, profits are independent of d in the presence of a downstream cartel.

As before, the retailers should have no incentive to defect from the cartel agreement. If a retailers considers to violate the (tacit) agreement, his optimal deviation price is

$$p^d = \begin{cases} \frac{12+5d}{16+8d} & \text{for} \quad d \in \left[0, 2(1+\sqrt{3})\right] \\ \frac{3}{4} - \frac{1}{2d} & \text{for} \quad d > 2(1+\sqrt{3}) \end{cases} \tag{5.8}$$

The optimal deviation price as a function of d has a kink at $2(1+\sqrt{3})$, because for $d > 2(1+\sqrt{3})$, the defector's rival is pushed out of the market. See Albæk and Lambertini (1998) for details. The corresponding deviation profits are

$$\pi_R^d = \begin{cases} \frac{(4+d)^2}{256(2+d)} & \text{for} \quad d \in \left[0, 2(1+\sqrt{3})\right] \\ \frac{(d-2)(d+1)}{16d^2} & \text{for} \quad d > 2(1+\sqrt{3}) \end{cases} \tag{5.9}$$

Now, consider the effects of a price floor. If the manufacturer chooses to impose a price floor $f > c$, it needs to have a destabilizing effect on the cartel. Otherwise, it is optimal for the manufacturer to choose $f \leq c$. An optimal price floor should satisfy $p^N < f < p^k$, because a floor below the Nash price is ineffective, and a floor above the collusive price is costly to the manufacturer. Then, given that the price floor binds, the manufacturer maximizes $2cq$ subject to the constraint that collusion is not feasible. Let $\overline{\beta}(c, f)$ be the critical discount factor for which collusion is just feasible. Now, the objective function can be rewritten as

$$\max_{\{c,f\}} c(1-f) \qquad \text{s.t.} \quad f \in \left[\frac{2+2c+cd}{4+d}, \frac{1+c}{2}\right] \quad \text{and} \quad \beta < \overline{\beta}(c, f). \tag{5.10}$$

To simplify this problem a bit, suppose that $d \in \left[0, 2(1+\sqrt{3})\right]$ and $f > p^d$, where p^d is given by (5.8). Then, collusion is not feasible under grim trigger strategies if

$$\begin{aligned} &\underbrace{(f-c)\frac{1}{2}\left(1 - f\left(1+\frac{d}{2}\right) + \frac{d}{2}\frac{1+c}{2}\right)}_{\pi^d} \\ &+ \frac{\beta}{1-\beta}\underbrace{\frac{1}{2}(f-c)\left(1-f\left(1+\frac{d}{2}\right)+\frac{df}{2}\right)}_{\pi^N} > \\ &\qquad \frac{1}{1-\beta}\underbrace{\frac{1}{2}\left(\frac{1+c}{2}-c\right)\left(1-\frac{1+c}{2}\left(1+\frac{d}{2}\right)+\frac{d}{2}\frac{1+c}{2}\right)}_{\pi^k.} \end{aligned} \tag{5.11}$$

This can be simplified to

$$\beta < \frac{1+c+cd-2f-df}{cd-df} \left(= \overline{\beta}(c,f)\right). \tag{5.12}$$

Since the manufacturer's profit is decreasing in f, it must be optimal to choose f such that (5.12) holds with equality. Then, collusion is prevented at the lowest cost to the manufacturer. Substituting $f(\beta, c)$ into the objective function yields

$$\pi_M(c,f) = c\left(1 - \frac{1+c+cd-cd\beta}{2+d-d\beta}\right). \tag{5.13}$$

At the optimum, $c = 1/2$ and

$$f = \frac{3+d-d\beta}{4+2d-2d\beta}. \tag{5.14}$$

It is straightforward to check that $f > p^d$ for all $\beta > 1/2$. The manufacturer's profit becomes

$$\pi_M^N = \frac{1+d-d\beta}{8+4d-4d\beta}. \tag{5.15}$$

As this is larger than $1/8$, the manufacturer is better off by using a price floor as a tool to prevent downstream collusion.

It may be instructive to examine the optimal price floor (5.14) more closely. Taking the first derivative with respect to d, one sees that

$$\frac{\partial f}{\partial d} = -\frac{1-\beta}{2(-2+d(-1+\beta))^2} < 0. \tag{5.16}$$

So, the price floor decreases in the degree of product differentiation. The reason is that collusion becomes harder to sustain as d increases on the interval $\left[0{,}2(1+\sqrt{3})\right]$. As a result, f is allowed to decrease. The same intuition applies for increases in the discount factor:

$$\frac{\partial f}{\partial \beta} = \frac{d}{2(-2+d(-1+\beta))^2} > 0. \tag{5.17}$$

When firms become more patient, collusion is easier to sustain, and the manufacturer has to increase the attractiveness of defection by increasing the price floor.

5.3 Concluding remarks

Price floors, or minimum RPM, can serve as an instrument to combat collusion between retailers. This is, to the best of my knowledge, a novel interpretation of RPM. The traditional view holds that RPM *promotes* collusion or prevents retailers from free-riding in the provision of service. The available empirical evidence is slated against the pro-collusion argument and, moreover, it is difficult to understand why a manufacturer would impose a price floor to sustain a retailer cartel. The service provision theory seems more promising, but it cannot explain price floors for simple goods. The theory advanced in this chapter explains the use of RPM for these markets and is consistent with recent experimental evidence (see Dufwenberg *et al.*, 2007).

In 2007, the U.S. Supreme Court decided that RPM must be judged by the rule of reason. This chapter provides an additional argument in favor of this decision by qualifying the existing pro-cartel arguments against RPM.

The reader may wonder whether the manufacturer has alternative anti-cartel instruments at its disposal. In particular, why would the manufacturer not simply report collusive behavior to the antitrust authority. This may be difficult when the manufacturer lacks hard evidence, as pure tacit collusion is virtually impossible to prosecute. Another strategy could be for the manufacturer to integrate with one downstream retailer and foreclose the other. This enables the manufacturer to prevent collusion and obtain the maximum attainable profits. Clearly, foreclosure is more profitable than a price floor, but may be blocked by the antitrust authority.

The results of this chapter by no means imply that each type of vertical restraint is anti-collusive. It is conceivable that other restraints, such as two-part pricing, actually induce collusion. Under two-part pricing, the manufacturer charges each retailer a linear price, plus a fixed franchise fee. The manufacturer could obtain the profits of the fully integrated structure by charging a linear price equal to his own marginal costs and set the franchise fee equal to the collusive profit. Then, the retailers are essentially forced to organize a cartel, otherwise they would be unable to repay the fee.

Part II

Collusion in auctions

Chapter 6

Let's buy it: An introduction to collusion in auctions

> There is one type of buyer who usually reveals the price he pays, and does not accept secret benefices: the government. The system of sealed bids, publicly opened with full identification of each bidder's price and specifications, is the ideal instrument for the detection of price-cutting.
>
> George J. Stigler (1964, p. 48)

6.1 Introduction

The importance of auctions in our modern economy can hardly be overstated. Auctions are used to sell various objects such as paintings, flowers, or spectrum rights and the list of items for sale on specialized auction websites such as eBay is virtually endless. In so-called reverse-auctions, a buyer auctions the right to supply to the seller who offers the lowest price. The amounts that are involved in reverse-auctions are massive. For instance, the public procurement outlays of the member states of the European Union in 2002 are estimated to total a staggering 1500 billion, or 16 percent of the European Union's GDP.[1]

The popularity of auctions is understandable. In contrast to alternative methods, like beauty contests, auctions are transparent and easy to implement. Furthermore, auctions tend to yield more revenue to the seller than negotiations (Bulow and Klemperer, 1996). And, unlike for instance lotteries, they tend to allocate

[1] This can be found at Europa.eu.int/comm/internal_market/publicprocurement/index_en.htm, accessed on March 28, 2008.

objects to the buyer who desires them most. Unfortunately, these properties quickly disappear in the presence of collusion. In auctions, bidders may set up a cartel, or a bidding ring, with the aim of increasing their profit, and at the expense of the seller. Collusion appears to be a pervasive problem of auctions. According to Froeb (1988), 81% of all Sherman Act infringements filed between 1979 and 1988 involved auctions. Economists have examined collusion in auctions for highway construction contracts (Porter and Zona, 1993), timber auctions (Baldwin, Marshall and Richard, 1997), and school milk auctions (Porter and Zona, 1999 and Pesendorfer, 2000). The costs of collusion can be significant. McMillan (1991) estimates that bid rigging in the Japanese construction industry raised prices by 16% to 33%. Porter and Zona (1999) estimate that bid-rigging in the Ohio school milk auctions raised prices by 6.5% on average.

In light of the widespread use of auctions and the occurrence of bid rigging, a thorough understanding of collusion in auctions is urgently needed. In recent years, a fairly extensive body of research emerged on the topic of collusion in auctions. However, this literature is rather inaccessible due to the highly technical nature of many key contributions. This chapter aims to give a concise overview of the main insights and provides the intuition behind the abstract propositions and theorems. Additionally, this survey discusses how the lessons of the literature can be applied to prevent and detect collusion in practice.

Krishna (2002, Ch. 11) and Salmon (2004) are other recent introductions. The present survey mainly differs from Krishna in its scope; he restricts attention to collusion in static standard auctions whereas this chapter also offers a discussion of the literature on repeated auctions and the recent experiences with the simultaneous ascending auction. Salmon (2004) is aimed at the applied auctioneer. He discusses the vulnerability of the simultaneous ascending auction to collusion and lists a few antidotes. This chapter's intended audience is the academic economist and therefore attempts to review the relevant academic literature. Throughout this chapter, it is assumed that the reader has some basic knowledge of auction theory and is familiar with the concepts in this literature. Good introductions to auction theory are McAfee and McMillan (1987) or Klemperer (1999).

The rest of this chapter is outlined as followed. Section 6.2 discusses collusion in static auctions. Focusing on a one-shot game helps to understand the informational problems bidders face when forming a cartel. It also gives some insight in how an auctioneer can prevent collusion by twisting the auction rules. The implicit assumption in this section is that bidders are able to collude even when they meet only once. In the conventional theory of collusion, cooperation is viewed as an equilibrium of a repeated game. The recent literature on collusion in repeated auctions is assessed in section 6.3. This sheds light on the structure of collusive agreements in various environments. Section 6.4 examines the scope for coordination in the simultaneous ascending auction. This auction is used to sell spectrum licenses, amongst others, and many observers have raised concerns that this format is particularly prone to collusive behavior. In this particular format, the seller or auctioneer has several opportunities to prevent or reduce the cost of collusion. These methods are discussed in section 6.5. Section 6.6 concludes.

6.2 Collusion in static auctions

6.2.1 How auctions solve the enforcement problem

Buyers can maximize their aggregate profit by forming a bidding ring. This simple observation does not directly imply that buyers will collude against the seller. If a buyer can increase his expected profit by deviating from the bidding ring's agreement, he will certainly do so. There is no honor among thieves. Rational buyers foresee this incentive to defect and refrain from joining a buyers' coalition altogether. A crucial challenge for a cartel is therefore to ensure that each member does not violate the agreements. In the jargon of the literature, collusion needs to be incentive compatible.

Buyers can solve this enforcement problem when they repeatedly interact with each other. The conspirators promise, explicitly or tacitly, to punish any deviation from the collusive agreement by vigorous competition. Then, provided that each potential defector is sufficiently patient and violations of the agreement are easily observed, the cartel members can sustain profits above the non-cooperative level. This insight is the celebrated folk theorem. See Friedman (1971) for a first formal statement. Porter (1983) offers an empirical analysis of a railroad cartel that allegedly used punishment strategies to sustain collusion.

The folk theorem suggests that collusion is infeasible in auctions that are conducted just once. Surprisingly, however, collusion may be sustained even in a static auction. This result is due to Robinson (1985), who shows that the second-price auction and the English auction allow the bidding ring to immediately punish a cheating cartel member.

It is easy to demonstrate the pro-collusive structure of these auction formats. Suppose that the bidding ring is complete and consists of n firms. The value of each bidder is common knowledge. Without loss of generality, let v_1 and v_2 denote the highest and second-highest value. The seller conducts a second-price auction to sell an indivisible good to one of the buyers. At least since the seminal work of Vickrey (1961), it is well-known that it is a weakly dominant strategy for each bidder to bid his value at this auction. If each bidder adheres to this (non-cooperative) strategy, the expected revenue is v_2. The bidder with the highest value has a payoff $v_1 - v_2$. However, the second-price auction admits another, more collusive equilibrium. The buyer with the highest value simply bids his value. All other ring members refrain from bidding, or submit a bid equal to the reserve price. This is a Nash equilibrium, because the designated winner (still) has a weakly dominant strategy to bid his value, and all other ring members cannot profitably acquire the object by changing their bid. The payoff of the ring increases from $v_1 - v_2$ to v_1.

This collusive equilibrium carries over to the English auction, as the second-price auction is weakly strategically equivalent to the English auction.[2] Graham and Marshall (1987) mention that "a retired auctioneer once noted that in 40 years of auctioneering, he had yet to attend an auction at which a ring was not present". Robinson's powerful finding that English auctions nurture collusion provides a simple explanation for the retired auctioneer's observation.

This form of collusion lowers the auctioneer's revenue, but maintains the efficiency of the non-cooperative equilibrium. On the basis of this, it can be argued that collusion is not problematic when the auctioneer only cares about achieving efficient outcomes. However, the second-price auction even admits collusive equilibria that are inefficient, a result first observed by von Ungern-Sternberg (1988). Suppose the bidding ring appoints a buyer with value below v_1 to be the designated winner. The ring's candidate simply submits a bid strictly above v_1 in the auction, and this cannot profitably be beaten by any other buyer. As before, the remaining ring members may just as well refrain from bidding. The second-price auction facilitates collusion by allowing the designated winner to credibly commit to a punishment of a violation of the ring agreement. Inefficient outcomes are less likely in the English auction, however, because the designated winner is unable to commit to a high price as the auction unfolds.

Alternative auction formats are less susceptible to collusion. In the static first-price auction, for instance, a designated winner who submits a low bid can be outbid by any buyer whose value is above the designated winner's bid. The work of Robinson (1985) and von Ungern-Sternberg (1988) suggest that when an auctioneer

[2] The second-price auction and the English auction are strategically equivalent for the special case of private values.

fears that buyers form a bidding ring, he should consider the use of an alternative allocation format.

6.2.2 Coordination

The above results demonstrate that, even in a one-shot interaction, firms can coordinate on a collusive equilibrium. However, there may be several collusive equilibria, as von Ungern-Sternberg (1988) noted, in which any firm may be the designated winner. The bidding ring, therefore, must somehow select an equilibrium. In other words, the bidding ring needs to determine which firm will win the auction.

This problem is trivial when values are common knowledge. But in many important environments it is more realistic to assume that buyers are privately informed about their value. As joint profits are maximized when the buyer with the highest value wins the auction, the cartel needs to induce the ring members to truthfully report their value. Graham and Marshall (1987) show how a bidder coalition can solve this coordination problem.

The main ingredients of their model are the following. One indivisible object is for sale in an English (or second-price) auction. There are n potential buyers, including a possibly incomplete bidding ring with $k \leq n$ members. Each buyer independently draws his value from a commonly known distribution function F. Buyers are privately informed about their value.

Before the actual auction, the ring members participate in a so-called *knockout*, organized by an independent agent, called the *ring center*. The ring center makes a fixed payment

$$P = \frac{E[\max\{Y_2^k - Y_1^{n \setminus k}, 0\}]}{k}$$

to each member, where Y_2^k is the second-highest value within the ring and $Y_1^{n \setminus k}$ is the highest value outside the ring. Then, buyers report their values (truthfully, in equilibrium) to the ring center. The ring center awards the buyer with the highest (reported) value with the right to represent the ring at the actual auction. There, both outsiders and the ring's nominee bid up to their true value. The remaining ring members have no incentive to submit a bid at the actual auction. Since all active buyers bid truthfully, the object is allocated to the ring's nominee if and only if he has the highest value. Finally, the ring's nominee pays the ring center kP in the event that he won the actual auction.

This knockout mechanism enables the ring to collude efficiently. At the knockout, the bidding strategy of the buyers cannot be affected by P, because that is a fixed transfer. The additional payoff of a ring member is zero if he loses the knockout, but it is his value minus the second-highest value of all n buyers should he win the knockout *and* the actual auction. These payoffs are the same as in a standard second-price auction, and therefore it is a weakly dominant strategy for each buyer to truthfully report his value at the knockout.

Each ring member's payoff is strictly above their hypothetical non-cooperative payoff, and increases in the number of buyers. It is therefore rational for buyers to join the bidding ring and, in equilibrium, the ring will consist of all potential buyers. Interestingly, Graham and Marshall note that the knockout mechanism (the theoretically optimal collusive mechanism) corresponds to how bidding rings operate in practice.

A weakness of Graham and Marshall (1987) mechanism is that it requires a ring center, who is willing to act as a banker for the colluding buyers. This ring center's expected surplus is exactly zero, by construction, but may be negative *ex post*. Would it be possible to organize an efficient cartel without 'breaking the budget' or a ring center? Mailath and Zemsky (1991) answer this question in the affirmative. Their solution (which extends to asymmetric buyers) is to use an Arrow-d'Aspremont-Gérard-Varet mechanism.[3] McAfee and McMillan (1992) point out that, when the bidding ring is complete, the ring members can efficiently collude by conducting a first-price sealed bid auction prior to the actual auction in which the members bid for the right to be the sole bidder. The proceeds are distributed evenly across all participants. Collusive schemes very similar to McAfee and McMillan's mechanism are quite common. A notable example forms a group of six pipemakers, who operated a knockout and became the very first cartel to be convicted under the Sherman Act.[4]

6.2.3 Constraints on collusion

The above section discussed efficient mechanisms that allow bidding rings to maximize joint profits. In practice, these mechanisms may not be feasible, for a number of reasons. The mechanisms considered so far require explicit communication and

[3] A mechanism is a set of allocation and payment rules. (In that sense, an auction is also a mechanism.) The Arrow-d'Aspremont-Gérard-Varet mechanism, also known as the expected externality mechanism, is constructed such that all agents honestly report their types and the payments between agents sum to zero. The interested reader is referred to Krishna (2002) for a more extensive discussion.

[4] Addyston Pipe and Steel Co. v. United States (1898), 85 F. 271.

side payments, which both may leave legal evidence of collusion. Given the illegal status of a bidding ring, a cartel that relies on communication or side payments faces a higher risk of being prosecuted.[5] Moreover, the side payments may attract non-serious buyers who are solely interested in receiving a share of the pie. In practice, this problem is often tackled by only making transfers to bidders who recently won an auction. However, this solution may not work when there are many serious buyers, or when the auction is conducted infrequently.

Ideally, from the perspective of buyers, a bidding ring employs an efficient mechanism that does not involve side payments. McAfee and McMillan (1992) demonstrate that, for the standard auction model, such a mechanism allows ring members to collect at most non-cooperative profits. This bold proposition is easily established using the revenue equivalence theorem.[6] Since the collusive mechanism is efficient, the allocation is the same as when the buyers act non-cooperatively. The revenue equivalence theorem then implies that the expected payments from each buyer to the auctioneer under the collusive mechanism and non-cooperative behavior differ by at most a constant. In the absence of side payments, the expected payment of a buyer with the lowest value must be zero. As a result, the collusive mechanism yields at most non-cooperative profit levels.

The inevitable conclusion is that a cartel that wishes to operate without side payments is forced to discard efficiency. This raises the question whether bidding rings can still profitably collude. In a private values environment, McAfee and McMillan (1992) show that a simple mechanism, bid rotation, may maximize the ring's expected profits. In other situations, the ring members cannot attain profits above the non-cooperative level. More precisely, McAfee and McMillan derive that a mechanism in which each ring member wins with equal probability maximizes expected ring profits if $\frac{1-F(v)}{f(v)}$ decreases in v. Non-cooperate bidding is optimal if $\frac{1-F(v)}{f(v)}$ increases in v.[7]

It may be instructive to sketch the proof of this result. The reader who wishes a more rigorous derivation is referred to the original paper. Chapter 7 studies optimal collusion for multidimensional auctions.

Consider a complete bidding ring and retain all other features of the standard auction model. The challenge of the ring is to design a mechanism that maximizes

[5] A hilarious example of how communication may lead to detection is provided by Porter (2005): "[O]ne conspiracy was investigated by the U.S. Department of Justice after a bidder submitted an envelope containing his own bid plus his notes from a pre-auction meeting."

[6] See Chapter 5 in Krishna (2002) for a detailed exposition.

[7] The condition that $\frac{1-F(v)}{f(v)}$ in v is equivalent to log-concavity, and is satisfied by many commonly used distributions, such as the uniform or the normal.

expected joint profits subject to the constraint that side payments are unavailable. By the revelation principle, it is without loss of generality to restrict attention to incentive compatible direct mechanisms in which each ring member reports his value to the mechanism. Conditional on the reports, the mechanism specifies a probability $q_i(v_i, v_{-i})$ that ring member i is awarded the right to be the sole bidder, where v_i is the bidder i and v_{-i} is the vector of values of all other bidders. Let π_i be buyer i's expected payoff under the mechanism. Incentive compatibility is equivalent to[8]

$$\frac{d\pi_i}{dv_i} = E_{-i}\left[q_i(v_i, v_{-i})\right] \tag{6.1}$$

$$\frac{\partial}{\partial v_i} q_i\left(v_i, v_{-i}\right) \geq 0. \tag{6.2}$$

The intuition behind these constraints is fairly straightforward. The conditions imply that a bidder's expected profit and that probability that he wins must increase (weakly) as his value increases. The inequality therefore requires the mechanism to be (weakly) efficient.

The expected profit of ring member i is $\int \pi_i(v) f(v) dv$. Using integration by parts, the no-side payments condition that $\pi(0) = 0$ and the condition for incentive compatibility, this can be written as $\int (1 - F(v)) E_{-i}[q_i(v_i, v_{-i})] dv$. The expected profit of the bidding ring becomes

$$E\left[\sum_{i=1}^{n} \pi_i(v)\right] = E\left[\sum_{i=1}^{n} \frac{1 - F(v)}{f(v)} q_i(v_i, v_{-i})\right]. \tag{6.3}$$

If $\frac{1-F(v)}{f(v)}$ increases in v, (6.3) is clearly maximized by letting the ring member with the highest value win the item. That is, the ring chooses q_i such that it increases in v_i. This implies efficiency and, as shown above, non-cooperative profits. For $\frac{1-F(v)}{f(v)}$ decreasing, the ring members wish to maximize (6.3) by awarding the ticket to the buyer with the lowest value. This implies that $q_i(v_i, v_{-i})$ is a decreasing function of v_i. By the second condition for incentive compatibility, however, $q_i(v_i, v_{-i})$ should be non-decreasing in v. The best the cartel can do, therefore, is to let each ring member win with equal probability.

There are several ways the ring can implement this. The ring members may take turns, rotate their bids, or submit identical bids. Although a cartel's expected profit is unaffected by the precise implementation of the optimal mechanism, practical

[8] A derivation of this result can be found in chapter 7 of this thesis.

considerations may induce firms to favor one method over another. Bid rotation, for instance, requires extensive communication between cartel members. Far less coordination is necessary for identical bidding, but the resulting conspicuous bid pattern may induce antitrust investigations.

6.2.4 Other complicating factors

Most papers that study collusion in auctions adopt the independent private values framework. This is a helpful and often realistic assumption, but may be an inaccurate description in some important settings. Allocative externalities, for instance, quickly arise when a crucial input is licensed to a number of competing firms. With externalities, an individual firm prefers an outcome in which no firm obtains a license, to a situation where one competitor obtains one (and subsequently becomes a dominant firm). Caillaud and Jéhiel (1998) study optimal collusion in the presence of externalities and find that efficient collusion becomes impossible when the externality is sufficiently large.

It is sometimes appropriate to extend the analysis to interdependent values. The object that is for sale may have a value that is common to all buyers, and each buyer only receives a private signal about the underlying value. The common value may derive from the possibility of resale in a secondary market, or the value of resources that can be extracted from the object. The most general analysis of auctions with interdependent values is Milgrom and Weber (1982). In that paper, Milgrom and Weber assume that buyers act non-cooperatively. Collusive behavior with interdependent values, however, has only been studied in special cases of Milgrom and Robert's affiliated values model.

One important special case is the pure common values model. With pure common values, buyers value the object the same, but this value is unknown and each buyer receives an informative signal about the true value. Following McAfee, McMillan and Reny (1989), it is easy to construct an efficient collusive mechanism. An all-inclusive ring could operate by simply having all ring members announce their signals and randomly selecting one buyer to represent the ring at the actual auction. Under this mechanism, buyers have a weakly dominant strategy to honestly report their signal because their message is independent of the probability that they are selected. The mechanism therefore allows the buyers to obtain all *ex post* surplus. The mechanism is also, by default, efficient, because each buyer holds the same value.

Hendricks, Porter and Tan (2003) study collusion in common value environments. Their main finding is that collusion is not always possible, because some buyers prefer the non-cooperative outcome to the collusive outcome. Hence, common values may hinder the formation of a bidding ring. The intuition is that buyers with a low signal give up little by reporting their signal to the ring (as they would probably lose the auction), and gain a lot because they prevent falling prey to the winner's curse if they win the auction. Buyers with a high signal, on the other hand, give up much by sharing their information (namely the profit in the actual auction) but gain little (just slightly more information about the object's true value). According to Hendricks *et al.*, their model can explain why in U.S. federal oil and gas lease auctions bidding rings are rare, even though joint ventures were legal before 1976.

6.3 Dynamic auctions

Auctions are often conducted sequentially. Governments, for instance, regularly procure more or less comparable construction contracts to a fixed set of firms. In view of the fact that, in many countries, firms have conspired in an effort to raise prices in such auctions, an important question is whether and, if so, how repeated interaction fosters collusion. Another, and more technical, reason to study repeated interaction is that in the static auctions that are discussed so far, adhering to the collusive agreement may not be incentive compatible. In a first-price auction, for instance, that is held only once, each buyer who loses the pre-auction knockout tries to outbid the ring's delegate.

There is a small literature that studies collusion in repeated auctions. The typical model in this literature is just an infinitely repeated standard auction and buyers have a common discount factor δ. Most of these papers focus on how the availability of side payments or communication affects optimal collusion. As the analysis in this literature is often complex, the discussion is restricted to just a description of the main insights.

Obviously, if ring members are able to freely communicate and to make monetary transfers, efficient collusion in a repeated second-price auction or English auction is feasible for any discount factor, simply because efficient collusion is even possible in a static environment. The folk theorem implies that this extends to the first-price auction, provided buyers are sufficiently patient. The interesting issue, therefore, is whether efficient collusion is still feasible when buyers cannot communicate or make side payments.

Fudenberg, Levine, Maskin (1994), Athey and Bagwell (2001) and Aoyagi (2007) show that efficient collusion is still possible even without explicit monetary transfers, for δ close to one. The key idea is that buyers can use asymmetric continuation payoffs as a substitute for side payments. That is, a player is rewarded for adhering to the cartel agreement by an increase in his expected future payoffs. An important drawback of these papers is that these papers assume that buyers' types are drawn from a discrete set. This assumption seems untenable in auctions.

The continuum types assumption is restored in Athey, Bagwell and Sanchirico (2004). They focus on optimal collusion in symmetric equilibria without side payments. Their main finding is surprising: bid rotation or identical bidding are optimal collusive scheme for a wide variety of parameters. Though the derivation is quite involved (and establishes interesting links between repeated games and mechanism design), the intuition is fairly straightforward. When buyers design a collusive scheme, they face a trade-off between efficiency and reducing informational rents. Ceteris paribus, efficiency is desirable because it maximizes the ring's *ex post* profit. However, as is well known from the mechanism design literature, it is costly to induce buyers to truthfully reveal their type. As monetary transfers are unavailable, and the possibility of transfers is the form of high future payoffs is limited, the buyers need to limit inter-temporal payments. The restriction to symmetric equilibria forms a constraint to such an extent that the cartel sacrifices efficiency in order to decrease the informational rents to zero. Just as in a static auction, when side payments are unavailable, a bidding ring cannot do better than collude using bid rotation.

Unlike Athey *et al.* (2004), Aoyagi (2003) and Skrzypacz and Hopenhayn (2004) find that a bidding ring can obtain higher profits than under bid rotation, even if monetary transfers are unavailable. The reason is that the latter papers are not restricted to symmetric equilibria. The collusive schemes of Aoyagi and Skrzypacz and Hopenhayn rely on asymmetric continuation phases. Initially, buyers are in a symmetric phase in which each buyer has the same discounted payoff. If a buyer has a sufficiently high value, the mechanism prescribes him to win the auction. Then, the bidding ring enters an asymmetric phase, in which the buyer who won the previous auction is allowed to win future auctions with a lower probability. That is, today's winners compensate today's losers by becoming tomorrow's losers. In the optimal mechanism, buyers do not overstate their value, because their value of winning the auction is relatively low, and they obtain a relatively low continuation payoff. Still, the optimal mechanisms do not allow the bidding ring to fully extract the surplus, as the right to win to auction is allocated inefficiently during the asymmetric continuation phase.

A potential drawback of these non-stationary strategies is that they require a high degree of communication. In an environment where side payments are impossible (*e.g.* in the presence of a vigilant antitrust authority), it seems likely that there are considerable constraints on communication as well.

6.4 The simultaneous ascending auction

The above sections discussed collusion in auctions in which one object or contract is awarded. In some environments, the auctioneer prefers to auction several objects or units simultaneously. Examples are electricity (Wolfram, 1998 and government bonds (Nyborg, Rydqvist and Sundaresan, 2002). This section will not discuss the scope for collusion in general multi-object auctions, since little is known about this issue.[9] The discussion in this section focuses on a particular format, the simultaneous ascending auction (SAA).[10]

The reasons for restricting attention to this format is that the SAA is one of the most prominent multi-object auctions, widely discussed in the literature, and the insights with respect to collusion can easily be extended to alternative auctions.

Since 1994 the Federal Communications Commission uses the SAA to license spectrum rights. Between 1994 and 1998, these auctions raised $ 22.9 billion for the U.S. Treasury (Cramton and Schwarz, 2000). Inspired by this apparent success, many countries quickly adopted this approach. In 2000, the British third-generation mobile-phone license auction gathered a spectacular revenue of $ 34 billion, or 2.5% of GNP and has been proclaimed "the biggest auction ever" (Binmore and Klemperer, 2002). However, the experience with the SAA in other countries is less positive. In the 1999 German second-generation spectrum auction, for instance, firms apparently colluded to the detriment of the German taxpaper (Grimm, Riedel and Wolfstetter, 2003). Cramton and Schwarz (2000, 2002) argue that the U.S. spectrum auctions are larded with instances of collusive behavior.

These mixed results suggest that the SAA can be sensitive to collusion. The important question is how this format fosters cooperation between buyers. Does the

[9] See Krishna (2002) for an overview of multi-object auctions.

[10] This auction is a natural extension of the English auction to simultaneously sell multiple objects. Milgrom, one of the designers of the SAA, provides an extensive discussion of this format in Milgrom (2000). In the SAA, the price for each object is gradually increased until each object is desired by at most one participant.

form of collusion in an SAA differ from collusion in a single-unit standard auction? Milgrom (2000) provides an answer, in the form of a simple example. Suppose that there are two buyers, 1 and 2, and two objects for sale, A and B. It is common knowledge that buyer 1 values each object at 10, and buyer 2 values them at 9. Then, the strategy of 'straightforward bidding', under which each buyer bids on each object for which the current price is below his value, results in the competitive equilibrium and a profit of 2 for buyer 1, and zero profits for each buyer. The seller's revenue is 18. There is also a collusive equilibrium, however, in which buyer 1 bids only on object A, and buyer 2 bids only on object B. Collusion can be sustained, because a deviation from this division is met by a reversion to 'straightforward bidding'. Then, given that the smallest eligible bid is zero, the buyers earn 10 and 9, and the seller is left with zero profits. Notice that this equilibrium in inefficient; an outcome is efficient if and only if buyer 1 receives both objects.

The multi-object feature of the SAA enables buyers to retaliate defection from the tacit agreement. This seems very similar to the way collusion operates in the static English auction. The SAA may be even more susceptible to collusion than the English auction, however. In a one-shot single-unit auction, weak buyers need to be compensated in order to refrain them from bidding competitively. By coordinating on an allocation of the objects, the ring members effectively make side payments to each other.

The scope for collusion in the SAA is not unlimited. When buyers are relatively asymmetric, or when there are relatively more buyers than objects, a collusive strategy along the lines of Milgrom's example becomes unstable. To see this, consider Milgrom's example again, but suppose that buyer 2 values both objects at 4. Then, it is profitable for buyer 1 to bid 'straightforward'. Buyer 1's profits increase from 10 to 12, and buyer 2's profits decrease from 4 to zero.

Brusco and Lopomo (2002) and Engelbrecht-Wiggans and Kahn (2005) study collusion in the SAA for two buyers and two objects. Buyers are privately informed about their values. They independently derive a sufficient condition for the existence of a collusive equilibrium. In this equilibrium, each buyer places a small bid on his most preferred object, and does not bid on the other object. Collusion is stable if each buyer expects the other buyer to have a sufficiently high value and buyers rank the objects differently. Of course, this equilibrium is inefficient if one buyer values both objects higher than the other buyer.

Brusco and Lopomo (2002) extend the analysis to the n buyers and two objects case. Interestingly, they find that the expected costs of collusion decreases in the number of buyers. The reason is, firstly, that collusion only occurs when two buyers have the highest values for each object and rank them differently. The probability that this occurs decreases in n. Secondly, even if collusion is possible, the expected price at which the last buyer drops out, and therefore the price which the remaining buyers pay, increases in n.

Cramton and Schwartz (2002) investigate a subset of the FCC spectrum auctions, namely the Personal Communications auction for broadband frequency blocks D, E, and F. In these auctions, a few firms signaled their collusive strategy through coded bids. For instance, the last 3 digits of a bid can refer to the firm's identity, like 288 for AT&T (288 on a telephone keypad gives ATT). Cramton and Schwartz (2002) discuss in detail how firms have used coded bids. They find that the firms who coded their bids paid significantly less than other winners.

6.5 Preventing collusion

6.5.1 Introduction

Collusion comes in a variety of forms, but the effect on revenue is invariantly negative. A seller interested in raising revenue–and it is the rare seller who is not–clearly wants to prevent collusion. Additionally, some forms of collusion, such as bid rotation or the type of collusion sometimes observed in SAA's, yield inefficient outcomes. Sometimes, a seller is also interested in achieving an efficient allocation (the FCC's single stated goal in the spectrum auctions was efficiency) and therefore has an additional incentive to obstruct collusion. Unsurprisingly, the rich variation in collusive behavior implies that there is no simple panacea. The aim of this section is to briefly discuss the main instruments that have been proposed in the literature.

The general insights of the industrial organization literature about how one could prevent collusion naturally extend to auctions. It is important to bear in mind that those findings, such as the impact of leniency policies, the effect of observability of actions, or the importance of multi-market contact, remain valid in the auction context. This section reviews anti-collusion techniques that are specific to auctions.

6.5.2 Collusion in standard auctions

As Robinson (1985) observes, collusion is highly stable in English auctions, even in a static setting. An auctioneer who suspects the presence of a bidding ring could change the format to a first-price auction. This comes at a cost. English auctions are often easier to conduct than first-price auction. English auctions are transparent, as bidders can observe that the auctioneer is following the rules, whereas in the first-price auction an auctioneer could–in exchange for a bribe–allow some bidders to adjust their bids. Moreover, bidding in the English auction is straightforward: in a private values setting each buyer has a weak-dominant strategy to bid up to his value. And the English auction yields the highest revenue among all efficient auctions with affiliated values. Finally, a switch to the first-price format may not even prevent collusion. Bidders can still organize a knockout and leave the seller with zero surplus.

Graham and Marshall (1987) are the first to suggest that an auctioneer who faces a cartel should consider to impose a high reserve price. It is well-known that in standard auctions with symmetric bidders, the auctioneer should set a reserve price (see Riley and Samuelson, 1981). When bidders act non-cooperatively, the optimal reserve price r is implicitly defined by

$$r = \frac{1 - F(r)}{f(r)}.$$

However, in the presence of an all-inclusive efficient cartel, there is just one serious bidder, and his value is drawn from the distribution of the highest order statistic F^n. The optimal reserve price for a bidding ring becomes

$$r = \frac{1 - F(r)^n}{nf(r)F(r)^{n-1}}.$$

Observe that the optimal reserve price increases in the number of bidders. The strategy of a high reserve price maximizes the seller's revenue, given the presence of a cartel. A high reserve price may also prevent collusion. McAfee and McMillan (1992) show that, for a uniform distribution, the bidders' expected revenue under collusion may be lower than under non-cooperative behavior, given that the seller imposes the optimal reserve price. This suggests that bidders have an incentive to commit not to collude. In a repeated auctions setting, Thomas (2005) finds that a reserve price greatly increases the critical discount factor for which collusion can be sustained.

Reserve prices have some drawbacks. The auctioneer may not be able to derive the optimal reserve price, or may be unable to commit to it, especially when no bidder is able or willing to submit an eligible bid. Calculating the reserve price requires knowledge of the distribution function, and an auctioneer may not be sufficiently sophisticated to do this. In multi-dimensional auctions, in which a firm's bid is a combination of a price and a quality level (see Che, 1993, for an early analysis), the optimal response is not a simple reserve price, as Kovacic, Marshall, Marx and Raiff (2006) recommend. Instead, the auctioneer should announce a reservation utility, which is the minimum level of utility that the firm's bid gives to the auctioneer (see chapter 7 for an explicit derivation). Typically, the reservation utility is non-linear in price and quality. A high reserve price may also reduce competition, as potential buyers refrain from entering the auction.

Although reserve prices increase the seller's revenue, the seller still prefers the bidders to act non-cooperatively. In a recent paper, Che and Kim (2006) demonstrate that even if bidders collude, the seller can attain any revenue as long as it is feasible in the absence of collusion. They show that in many settings one can design a mechanism that gives the seller his expected revenue under non-cooperative behavior of sellers. Their idea is related to the 'sell-the-firm' solution in optimal risk-sharing contracts. Of course, the drawbacks that apply to reserve prices apply *a fortiori* to such a mechanism.

In the absence of side payments, an inefficient mechanism, such as bid rotation or identical bidding may be optimal for a bidding ring. In those cases, McAfee and McMillan (1992) suggest that the seller may try to actively meddle with the agreement. For instance, with identical bidding the ring abuses the buyer as a randomization device. The seller can prevent this by, in the case of a tie, allocating the object to the buyer whose name comes first in the alphabet.

6.5.3 Collusion in simultaneous ascending auctions

Cramton and Schwarz (2000) and Salmon (2004) discuss several methods to deter collusion in SAA's. Salmon argues that the auctioneer should encourage entry to prevent collusion. When the number of bidders increases relative to the number of objects, it becomes harder and more unlikely that the bidders are able to coordinate on a particular allocation. The seller can promote competition by announcing the auction and its details well in advance. Or he may favor new bidders by awarding bidding credits or reserving one object to a newcomer. Of course, an alternative method increase the relative number of bidders is to reduce the number of objects. By lumping some objects together, it becomes more profitable for a bidder to deviate from the tacit agreement.

Cramton and Schwarz (2000) also contribute to the discussion of the desirability of a high reserve price. They argue that a high reserve price reduces the number of rounds, as the early rounds at low prices are skipped. This implies that firms have less opportunities to coordinate. A more direct method to reduce the scope for coordination is to limit bidder's discretion in setting bids to prevent coded bidding. Cramton and Schwarz offer an insightful discussion of the desirability of revealing identities during the SAA. The main reason to conceal bidder identities is that it helps to prevent collusion. It also hinders large firms to develop a reputation of aggressive bidding. Conveying this information is appropriate in the presence of significant 'identity-dependent' externalities, which may arise when a firm expects vigorous competition from firm A, but not from firm B. Making identities public also contributes to the auction's transparency. Milgrom (2000) argues that, since large firms are typically able to find out the true identities of bidders, for instance through detective work, these identities should be made public in order not to disadvantage small firms.

6.5.4 Detecting collusion

An auctioneer may not know with certainty that a bidding ring exists. Without a firm belief that some buyers coordinate, the seller has no incentive to adjust the auction format to accommodate for collusion. Even worse, without hard evidence of its presence, a bidding ring cannot be prosecuted. This raises the question of how one can detect collusion in auctions. Unfortunately, the theory provides little guidance. The small empirical literature on collusion in auctions offers some detection techniques, but these methods give at most suggestive evidence of collusion. Indeed, in their study of the highway construction procurement auctions, Porter and Zona warn the reader that their methods "will be poor substitutes for a wiretap or a disclosure by a dissident ring member."

There are many forms of collusion, and it is hard to find statistical evidence of coordination without some prior knowledge, or at least a working hypothesis, of how the bidding ring proceeds. When the researcher assumes a particular type of collusive behavior, he can exploit differences between the observable implications of collusion and non-cooperative behavior. For instance, the detection strategy in Porter and Zona (1993) is to compare the losing bids of cartel members and non-cartel members. A non-cartel member's bid is intended to maximize expected profit, whereas a cartel members losing bid is supposed to create the appearance of genuine competition. The latter bid may therefore be uncorrelated to observable cost variables. Porter and Zona (1993)'s methodology suffers from two severe drawbacks. First, it requires knowledge of the identity of ring members. Second, and most importantly, their detection method is self-defeating. Once bidding rings realize that an antitrust authority analyzes losing bids, it is costless to submit losing bids that are ostensibly competitive and circumvent detection.

Bid rigging is impossible to detect on the basis of bids alone, but there is one exception; when firms submit identical bids. As McAfee and McMillan (1992) and Athey *et al.* (2004) show, identical bidding may be optimal when buyers cannot use monetary transfers. History is replete with examples of identical bidding. Mund (1960) reports several suspicious cases from the 1950s. The U.S. Department of Agriculture, for instance, received 23 identical bids of $ 519 in a procurement auction for microscopes. In 2000, the Italian Competition Authority fined five pharmaceutical companies who submitted identical bids in an auction for diagnosis drugs, see Albano, Buccirossi, Spagnolo and Zanza (2006) for a discussion. Very recently, nine producers of generic medicines (who all happened to be organized in a trade union) in the Netherlands announced identical prices. The suspicion of coordination is strengthened by the fact that two other firms (who are not associated with the trade union), charge different prices.[11]

Given that identical bids are extremely unlikely to result from non-cooperative behavior, why do firms still apply this strategy? One explanation is that, even though identical bids unveil the presence of a cartel, it requires little communication. Selecting a ring's candidate, and mimicking competition through phony bids requires much more communication, and therefore a higher probability of conviction. Moreover, few courts accept identical bids as sufficient proof of collusion, and firms can safely rely on this strategy.

The U.S. Department of Justice lists a number of possible indications of collusion in procurement auctions that may be useful in practice. For instance, a firm that submits a bid in spite of the fact that it is clearly unable to supply the object or service, may be trying to simulate competition. Furthermore, the sealed bids from different firms may be written in the same handwriting, or a firm's spokesperson could make a revealing slip of the tongue.

[11] *Trouw*, "Pillenfabrikanten beticht van onderlinge prijsafspraken", Jan. 25, 2008. Strikingly, the trade union (Bogin) happens to be located in the *same* building as the Dutch Competition Authority.

6.6 Concluding remarks

Whether they participate in an auction or an 'ordinary' market, prospective conspirators need to address several challenges. As Stigler (1964) observed, cartel members need to ensure that unilateral defection from the cartel agreement is unprofitable. This requires a monitoring system and a credible punishment strategy. Also, a cartel needs to coordinate its actions. Besides fixing prices, firms may need to coordinate on the product range, product quality, or investments in R&D or capacity. Any agreement on these actions implies a certain division of the spoils and each firm in the agreement has an incentive to argue for a larger share of the pie. In auctions, these problems are often solved by design. In a typical auction, the seller has inelastic supply and ranks bids solely according to prices. This greatly facilitates coordination as ring members only need to agree on a price. Ascending auction formats such as the English auction or the SAA enable bidders to directly observe a deviation by a ring member and can instantly respond.

Hence, the nature of many auction formats provides a fertile breeding ground for cartels. The auctioneer is not helpless, however. There are several instruments at his disposal to prevent bid rigging, or at least mitigate its adverse effects. He can impose or raise the reserve price or change the auction format. In some cases, even a simple adjustment of a seemingly innocuous bidding rule can be sufficient to induce non-cooperative behavior.

Though the literature on collusion in auctions is fairly rich, there remain several topics that deserve a fuller treatment. For instance, incomplete rings at English auctions are well understood, but little is known about incomplete rings at first-price auctions. In a first-price auction, an outsider may not be willing to join the ring, and this has repercussions on the ring's strategy.

In static auctions, the auctioneer may respond by setting a higher reserve price. An important insight of the theory of collusion in dynamic auctions is that optimal cartel schemes are asymmetric in the absence of monetary transfers (Aoyagi, 2003 and Skrzypacz and Hopenhayn, 2004). This suggests that the auctioneer should adopt a history-dependent reserve price policy. Moreover, the optimal reserve price may discriminate between firms, being higher for instance for a firm that won the previous auction.

Bidding rings often organize a knockout *after* the actual auction in which they auction the object amongst themselves. McAfee and McMillan (1992) and Lopomo, Marshall and Marx (2005) give examples of real-world rings that use this mechanism. It is easy to see that, without prior communication, an *ex post* knockout is inefficient and yields suboptimal collusive profits. It would be interesting to understand the rationale behind this collusive practice.

A potential explanation is that an *ex post* knockout requires less communication, because it is conducted less frequently than an *ex ante* knockout, which is organized before every auction. Hence, the *amount* of communication that is involved in a scheme seems to be an important determinant of the optimal mechanism. Existing papers either assume that communication is costless, or impossible. A fruitful approach therefore seems to consider optimal collusion when bidders can vary the intensity or amount of communication.

Auctions are not isolated events. Often, buyers interact before and after the auctions. Future work may shed more light on how market interactions influence the propensity to collude in auctions (and vice versa).

Chapter 7

Collusion in multidimensional auctions

7.1 Introduction

Public procurement outlays constitute a large fraction of GDP in Western countries. Dimitri, Piga and Spagnolo (2006) report that the value of public procurement in EU countries is about 16% of GDP and 20% in the United States. Given the massive amounts of public money involved in procurement it is important that these funds are spend efficiently. Unfortunately, collusion seems to be a significant problem in public procurement.[1] Collusion tends to inflate prices and may yield inefficient allocations. Understanding how collusion in procurement takes place and how governments can respond to it is therefore an important research goal.

Since public procurement is typically conducted by means of auctions, the study of collusion in procurement can learn much from the theory of collusion in auctions. As seen in chapter 6, the models in this literature focus on auctions in which the auctioneer only cares about the price of the good. In procurement, the government also cares about the quality of the good. This implies that the government often faces a trade-off when awarding the contract to a firm. Should the low quality, low price firm win the procurement auction, or should the government select the high quality, high price firm? In practice, contracts are typically awarded to either the firm that submits the lowest price or the firm that submits the economically

[1] Albano, Buccirossi, Spagnolo and Zanza (2006) provide several examples of recent cases of collusion in public procurement.

most advantageous offer.[2] In the former case, the selected firm should meet certain quality criteria. In the latter case, the government adadopts a scoring rule, that weighs the price and quality of the offer to order the firms' proposals.

This chapter extends the results of McAfee and McMillan (1992) to a two-dimensional setting. The analysis builds on Che's (1993) framework of two-dimensional auctions. In Che (1993), a buyer has quasilinear preferences over the price and the quality of the good she buys. Firms have a convex cost of producing quality and are privately informed about their relative efficiency of producing quality. The findings of McAfee and McMillan straightforwardly carry over. This exercise helps to understand one of the key results in the theory of collusion in auctions. In this sense, the analysis below can be seen as a technical appendix to chapter 6.

That interpretation would, however, under-appreciate the added value of a two-dimensional focus over McAfee and McMillan's one-dimensional focus. In particular, the literature on collusion in one-dimensional auctions suggests that the government can use an aggressive reserve price policy.[3] This policy is suboptimal in a two-dimensional setting. When the government commits to a low reserve price, firms can still collude and set quality inefficiently. This chapter proposes an alternative auction format, the reservation utility auction. In this auction, the government requires firms to offer at least the reservation utility. A reservation utility policy places a restriction on the admissible price quality combinations and is therefore the natural extension of a reserve price policy to a two-dimensional auction format. This reservation utility auction yields the government a strictly higher payoff than an auction with just a reserve price. The reason is that a reservation utility auction allows firms to choose their quality level in an *ex post* efficient manner.

The remainder of this chapter is as follows. The model is presented in section 7.2. The non-cooperative equilibrium is characterized in section 7.3. Section 7.4 shows how the optimal collusive mechanisms follow from standard mechanism design. To study collusion, the analysis follows McAfee and McMillan (1992) by assuming that firms design and commit to a collusive mechanism before they learn their types. Anti-collusive strategies are studied in section 7.5. Concluding remarks are in section 7.6.

---

[2] For a good overview of actual procurement practices, see Carpineti, Piga and Zanza (2006).

[3] An agressive reserve price increases the government's payoff and simultaneously may help to deter collusion. McAfee and McMillan (1992) first demonstrated the efficacy of a reserve price in a one-dimensional auction in the presence of a cartel. See Thomas (2005) for an extensive numerical exposition of this result. Kovacic et al. (2006) recommend practitioners to use a low reserve price policy to deter collusion.

7.2 The model

7.2.1 Overview

The set-up closely follows Che (1993). There are two types of players: the government and $n \geq 2$ firms. The government wishes to obtain an indivisible unit of a good or service. The government is unable to produce this good itself, so it has to buy the good from a firm. An alternative assumption with the same implication might be that the cost of producing for the government is higher than the cost for the least efficient firm. The government employs a sealed bid auction mechanism. This means that all firms simultaneously submit their offer, consisting of a price p and a quality level q. The government selects the firm that submits the best offer at the auction.

7.2.2 Government

When the government obtains the good from firm i, it receives a utility level

$$U(p_i, q_i) = V(q_i) - p_i, \tag{7.1}$$

where q_i is the quality supplied by firm i and p_i is the price paid from the government to firm i. The function $V(\cdot)$ evaluates the quality of the good and satisfies $V'(\cdot) > 0$, $V''(\cdot) \leq 0$, $\lim_{q \to 0} V'(\cdot) = \infty$, and $\lim_{q \to \infty} V'(\cdot) = 0$. After the auction, it observes the price and quality offers of all firms and awards the contract to the firm offering the highest utility, given that it is non-negative.

7.2.3 Firms

When firm i is selected by the government to supply the good or service, its profit is

$$\pi_i(p_i, q_i) = p_i - c(q_i, \theta_i), \tag{7.2}$$

where $c(q_i, \theta_i)$ is the firm's cost of supplying the good with quality level q_i. The cost function is increasing in the firm-specific cost parameter θ_i. Each firm is privately informed about its own cost parameter. The government and the $n - 1$ other firms perceive θ_i as being drawn from a continuous distribution function $F(\theta) : [\underline{\theta}, \overline{\theta}] \to [0, 1]$. Suppressing the firm subscript and arguments, it is assumed that $c_q > 0$, $c_\theta > 0$, $c_{qq} \geq 0$, $c_{\theta\theta} \geq 0$, and $c_{q\theta} > 0$ holds for every firm. Furthermore, the social surplus resulting from a sale between the least efficient firm and the government is at most zero. Technically, $\max_q\{V(q) - c(q,\overline{\theta})\} = 0$. This condition is just a normalization. The government is exactly indifferent between provision of the good by the least efficient firm and its best outside option (which could be foregoing the product or producing it in-house).

Before firms learn the realization of their cost parameter, they may form a cartel by committing to a collusive mechanism. Since firms are assumed to be endowed with commitment power, firms are unable to cheat on the cartel agreement once they have committed themselves to it. Using the terminology introduced by McAfee and McMillan (1992), the analysis below considers both weak and strong cartels. A weak cartel is unable to make transfers between firms whereas a strong cartel is. All firms need to commit to the mechanism. If one or more firms reject it, firms act non-cooperatively at the procurement auction.

7.2.4 Timing

The timing of moves is as follows. First, the firms may commit to a collusive mechanism. It is without loss of generality to assume that the firms commit to a mechanism, because bidding non-cooperatively is a mechanism as well. Then, each firm privately learns its cost parameter and reveals its private information to the mechanism. The mechanism subsequently recommends a particular action to every firm and every firm adheres to this recommended action. Finally, the government simply awards the contract to the firm offering the best offer. Quality is assumed to be contractible, so the government knows the realization of quality at the contracting stage.

7.3 The non-cooperative equilibrium

This section derives the non-cooperative equilibrium bid strategies. Given the *ex ante* symmetry of firms, it is natural to focus on a symmetric equilibrium in which all firms use the same bid functions $\{p(\theta_i),\ q(\theta_i)\}$ to determine their optimal price and quality offer as a function of the privately known cost parameter. This situation was first studied by Che (1993) and all results in this section can be found there.

As a first step in finding the equilibrium, lemma 7.1 states that one can restrict attention to deterministic quality offers. An intuition behind this separability condition is that firms first choose quality such that the size of the pie (the sum of firm profit and government utility) is maximized, and then select a price to offer a division of the pie.

Lemma 7.1 (Che, 1993)**.** *In any non-cooperative equilibrium, each firm i offers a quality level* $q^*(\theta_i)$*, where*

$$q^*(\theta_i) = \operatorname*{argmax}_q \{V(q) - c(q, \theta_i)\}.$$

Proof. Consider a firm deciding between two offers with the same probability of winning. These offers, (q, p) and $(q^*(\theta_i), p')$, are such that $V(q^*(\theta_i)) - p' = V(q) - p$. Clearly, both offers imply the same probability of winning, because the government is indifferent between them. The profit of the firm, conditional on winning with an offer $(q^*(\theta_i), p')$, is

$$\begin{aligned}
\pi(p', q^*(\theta_i)) &= p' - c(q^*(\theta_i), \theta_i) \\
&= V(q^*(\theta_i)) - V(q) + p - c(q^*(\theta_i), \theta_i) \\
&= V(q^*(\theta_i)) - c(q^*(\theta_i), \theta_i) - V(q) + c(q, \theta_i) + p - c(q, \theta_i) \\
&\geq p - c(q, \theta_i),
\end{aligned}$$

where the inequality follows because $q^*(\theta_i)$ maximizes $V(q, \theta_i) - c(q, \theta_i)$. ■

Lemma 7.1 greatly simplifies the analysis. Instead of solving a two-dimensional problem, one now only needs to consider the one-dimensional problem of characterizing the price function $p(\theta_i)$. Assuming that $V(q) - p(\theta_i)$ is decreasing in the cost parameter θ_i, the equilibrium probability that a firm wins the procurement auction is monotonically decreasing in θ_i. Below, this assumption is shown to hold. So, the expected profit of a firm i that has a cost parameter θ_i, but charges a price as if $\theta_i = x$, is

$$\begin{aligned}
E[\pi_i] &= Pr\left(x < \min\left\{\theta_j\right\}_{j\neq i}^n\right)(p(x) - c(q^*(x), \theta_i)) \\
&= H(x)(p(x) - c(q^*(x), \theta_i)), \qquad (7.3)
\end{aligned}$$

where $H(x) \equiv \left(1 - F(x)\right)^{n-1}$ denotes the probability that a firm with cost parameter x wins the procurement auction. If $p(\theta)$ is part of a symmetric non-cooperative equilibrium, firm i maximizes (7.3) by setting $x = \theta_i$. Using standard techniques from the auction theory literature, consult *e.g.* Krishna (2002) for a good overview, one can solve for the equilibrium price function. The next proposition gives the optimal price and quality offered by each firm in the non-cooperative equilibrium.

Proposition 7.1 (Che, 1993)**.** *In the unique symmetric equilibrium in pure strategies, each firm i with cost parameter θ_i offers*

$$\begin{aligned} p(\theta_i) &= c(q^*(\theta_i), \theta_i) + \int_{\theta_i}^{\overline{\theta}} \frac{H(t)}{H(\theta_i)} c_\theta(q^*(t), t) dt, \\ q(\theta_i) &= q^*(\theta_i). \end{aligned}$$

Proof. A firm with cost parameter θ_i maximizes (7.3) with respect to x. The first-order condition, evaluated at $x = \theta_i$, is

$$\frac{\partial}{\partial \theta_i}(H(\theta_i)p(\theta_i)) - \frac{\partial}{\partial \theta_i}(H(\theta_i)c(q^*(\theta_i), \theta_i)) + H(\theta_i)c_\theta(q^*(\theta_i), \theta_i) = 0.$$

Integrating over the interval $[\theta_i, \overline{\theta}]$ and noting that $H(\overline{\theta}) = 0$ gives the solution for $p(\theta_i)$. Observe that the probability of winning is indeed decreasing in θ_i because

$$\begin{aligned} \frac{\partial}{\partial \theta_i}(V(q^*(\theta_i)) - p(\theta_i)) &= V_q q_\theta - c_q q_\theta - c_\theta + c_\theta \\ &\quad + \frac{h(\theta_i)}{H(\theta_i)^2} \int_{\theta_i}^{\overline{\theta}} H(t) c_\theta(q(t), t) dt \\ &= \frac{h(\theta_i)}{H(\theta_i)^2} \int_{\theta_i}^{\overline{\theta}} H(t) c_\theta(q(t), t) dt < 0, \end{aligned}$$

where the inequality follows because $V_q = c_q$ from lemma 7.1, $h(\theta_i) < 0$ by definition, and $c_\theta > 0$ by assumption. ■

In the non-cooperative equilibrium, the expected profit of a firm i with cost parameter θ_i is $\int_{\theta_i}^{\overline{\theta}} H(t) c_\theta(q^*(\theta_i), \theta_i) dt$. Before the firm learns its cost parameter, the *ex ante* expected profit is

$$\begin{aligned} E[\pi_i^N] &= \int_{\underline{\theta}}^{\overline{\theta}} \int_x^{\overline{\theta}} H(t) c_\theta(q^*(t), t) dt f(x) dx \\ &= \int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{\theta}}^{t} H(t) c_\theta(q^*(t), t) f(x) dx dt \\ &= \int_{\underline{\theta}}^{\overline{\theta}} F(t) H(t) c_\theta(q^*(t), t) dt. \end{aligned} \tag{7.4}$$

where the third equation follows from changing the order of integration. Clearly, when firms are colluding, they require an *ex ante* expected profit at least as large as (7.4).

7.4 Optimal collusive mechanisms

From now on, assume that firms may form a cartel. Before the firms learn their cost parameter, they design a collusive mechanism that maximizes joint expected profits.

7.4.1 Some mechanism design

The problem for the firms of how to collude is not straightforward. First, firms are privately informed about their own cost parameter and therefore must somehow select a firm that ultimately wins the procurement auction. A second and closely related problem is that all losing firms must be compensated. If their expected collusive profits are lower than the non-cooperative profits the firms will reject the proposed mechanism. Third, the firms may not be able to make transfers. A firm that just won the procurement auction and donates large sums of money to losing firms may raise the suspicion of the authorities.

Stated in the language of mechanism design theory, the first problem means that the mechanism should be incentive compatible. The second problem implies that the mechanism should satisfy the individual rationality constraint. If the third problem is applicable, one needs to impose the restriction that the mechanism does not stipulate transfers between firms.

The revelation principle (Myerson, 1979) implies that one can focus on incentive compatible direct mechanisms. In a direct mechanism, it is optimal for every firm to truthfully reveal its private information to the mechanism. Let $\theta_{-i} \equiv \{\theta_1, \theta_2, \ldots, \theta_{i-1}, \theta_{i+1}, \ldots, \theta_{n-1}, \theta_n\}$. Then, if $n-1$ firms report that their cost parameters are θ_{-i} and firm i reports $\theta_i = x_i$, the mechanism selects firm i to be the designated winner with probability $a_i(x_i, \theta_{-i})$. The winning firm is required to deliver the good with quality $q_i(x, \theta_{-i})$. Conditional on all reports, firm i receives an expected transfer of $b_i(x_i, \theta_{-i})$ from the mechanism. Then,

Lemma 7.2. *A mechanism described by* $\{a_i(\theta_i, \theta_{-i}), b_i(\theta_i, \theta_{-i}), q_i(x, \theta_{-i})\}$ *is incentive compatible if and only if*

$$\frac{dE\left[\pi_i(\theta_i)\right]}{d\theta_i} = -a_i(\theta_i, \theta_{-i})c_\theta(q_i(\theta_i), \theta_i)$$

and

$$a_i'(\theta_i, \theta_{-i}) \leq 0.$$

Proof. The proof of this result is standard in the mechanism design literature, but is included for the sake of completeness. Consider firm i with cost efficiency θ_i, but announces to the mechanism that its type is x. Given that all other firms truthfully submit their information to the mechanism, firm i maximizes its expected profit

$$E\left[\pi_i(x,\theta_i)\right] = b_i(x,\theta_{-i}) - a_i(x,\theta_{-i})c(q_i(x),\theta_i)$$

with respect to x. In an incentive compatible mechanism, it is optimal for the firm to announce $x = \theta_i$. Therefore, the necessary condition for the firm's maximization problem is

$$\left.\frac{\partial \pi_i(x,\theta_i)}{\partial x}\right|_{x=\theta_i} = b_i'(\theta_i,\theta_{-i}) - a_i'(\theta_i,\theta_{-i})c(q_i(\theta_i),\theta_i) \\ - a_i(\theta_i,\theta_{-i})c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i) = 0. \quad (7.5)$$

Given that the mechanism is incentive compatible, the firm optimally chooses $x = \theta_i$ and the expected profit of firm i can be written as

$$E\left[\pi_i(\theta_i)\right] = b_i(\theta_i,\theta_{-i}) - a_i(\theta_i,\theta_{-i})c(q_i(\theta_i),\theta_i).$$

Totally differentiating the above expression gives

$$\frac{dE\left[\pi_i(\theta_i)\right]}{d\theta_i} = b_i'(\theta_i,\theta_{-i}) - a_i'(\theta_i,\theta_{-i})c(q_i(\theta_i),\theta_i) \\ - a_i(\theta_i,\theta_{-i})(c_\theta(q_i(\theta_i),\theta_i) + c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i)). \quad (7.6)$$

Subtracting (7.5) from (7.6) gives the necessary condition

$$\frac{dE\left[\pi_i(\theta_i)\right]}{d\theta_i} = -a_i(\theta_i,\theta_{-i})c_\theta(q_i(\theta_i),\theta_i).$$

Now, in order to obtain the sufficient condition for incentive compatibility, observe that the sufficient condition for the firm's maximization problem is, evaluated in $x = \theta_i$,

$$b_i''(\theta_i,\theta_{-i}) - a_i''(\theta_i,\theta_{-i})c(q_i(\theta_i),\theta_i) - 2a_i'(\theta_i,\theta_{-i})c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i) \\ - a_i(\theta_i,\theta_{-i})\frac{\partial}{\partial x}(c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i)) \leq 0. \quad (7.7)$$

Differentiating the necessary condition for profit maximization (7.5) with respect to θ_i gives

$$b_i''(\theta_i,\theta_{-i}) - a_i''(\theta_i,\theta_{-i})c(q_i(\theta_i),\theta_i) - 2a_i'(\theta_i,\theta_{-i})c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i) \\ - a_i(\theta_i,\theta_{-i})\frac{\partial}{\partial x}(c_q(q_i(\theta_i),\theta_i)q_i'(\theta_i)) - a_i'(\theta_i,\theta_{-i})c_\theta(q_i(\theta_i),\theta_i) = 0. \quad (7.8)$$

Relying once again on the same trick as before allows one to obtain a convenient sufficient condition for incentive compatibility. Subtracting equation (7.8) from (7.7) shows that the sufficient condition can be written as

$$a_i'(\theta_i,\theta_{-i})c_\theta(q_i(\theta_i),\theta_i) \leq 0.$$

However, by assumption, $c_{\theta_i}(q_i(\theta_i),\theta_i)$ is strictly positive. So, the sufficient condition for incentive compatibility reduces to

$$a_i'(\theta_i,\theta_{-i}) \leq 0.$$

■

Hence, incentive compatibility requires that the expected profit of every firm in the mechanism is decreasing in its cost parameter. Moreover, the mechanism should be (weakly) efficient. Observe that the non-cooperative outcome can be replicated via an incentive compatible mechanism in which each firm truthfully announces its cost parameter, and the mechanism submits for every a bid $\{p(\theta),q^*(\theta)\}$ to the procurement official. However, the interesting question is whether the firms can construct an alternative mechanism that attains profits above the non-cooperative level. McAfee and McMillan (1992) show that the optimal collusive mechanism depends on the ability of firms to make side transfers. Weak cartels may be unable to attain profits above the non-cooperative level. In a strong cartel, *i.e.* when cartel members are allowed to make transfers, firms are able to obtain the full surplus. The next two sections extends these results to two-dimensional auctions.

7.4.2 Weak cartels

By definition, members of a weak cartel cannot make explicit monetary transfers to each other.[4] This implies that $b_i(\theta) = 0$ for all θ. As a result, the only instruments

[4] Implicit transfers may be possible if the government regularly conducts procurement auctions. In that case, the cartel members may *e.g.* temporarily exclude a previous winner from future auctions.

left to the designer of the mechanism are the allocation functions $a_i(\theta)$ and quality function $q_i(\theta)$.

Absent asymmetric information, cartel profits would be maximized if the collusive mechanism is efficient. This requires $a_i' < 0$. Then, the firm with the most advanced technology is selected to be the winner of the auction and this firm fully extracts the social surplus by supplying a quality q^*. If a weak cartel uses an efficient mechanism, the *ex ante* expected profit of firm *i* is

$$\begin{aligned} E[\pi_i] &= \int_{\underline{\theta}}^{\overline{\theta}} \pi_i(t) f(t) dt \\ &= \pi_i(t) F(t)\big|_{\underline{\theta}}^{\overline{\theta}} - \int_{\underline{\theta}}^{\overline{\theta}} \frac{d}{dt} \pi_i(t) F(t) dt. \end{aligned}$$

The second equation follows from integration by parts. Clearly, in the above expression $\pi(\overline{\theta}) = 0$ and $F(\underline{\theta}) = 0$. From lemma 7.2, any incentive compatible mechanism satisfies $\frac{dE[\pi_i]}{d\theta_i} = -a_i c_\theta$, where the arguments are omitted. Furthermore, efficiency implies that $a_i(\theta_i) = H(\theta_i)$. Using these observations expected profits can be rewritten as

$$E[\pi_i] = \int_{\underline{\theta}}^{\overline{\theta}} F(t) H(t) c_\theta(q^*(t), t) dt. \tag{7.9}$$

But this equals the non-cooperative profit level, as given by equation (7.4). As a result,

Lemma 7.3. *In any efficient weak collusive mechanism, firms attain non-cooperative profits.*

This 'impossibility theorem' mirrors a related finding by McAfee and McMillan (1992). They show that, in the context of one-shot first-price auctions, the dual condition of efficiency and zero profits for cartel members with a valuation below the reserve price implies that the cartel cannot improve on the non-cooperative outcome. The intuition for this result is straightforward. The celebrated Revenue Equivalence Principle (REP) from auction theory states that if values are independently and identically distributed and bidders are risk neutral,

> "[...] any symmetric and increasing equilibrium of any standard auction, such that the expected payment of a bidder with value zero is zero, yields the same expected revenue to the seller." (Krishna, 2002).

This increases the expected profit of all other firms and therefore constitutes a dynamic transfer. See for instance Skrzypacz and Hopenhayn (2004) for a model along these lines.

The procurement auction in this chapter can be interpreted, after some changes of variables, as a standard first-price auction and is therefore subject to the logic of the REP as well. Given that the firms are risk neutral, and their cost parameters are identically and independently distributed, any efficient mechanism implies that each firm earns its informational rent, plus some constant. Because the least efficient firm does not have an informational rent, and necessarily earns zero profits, the REP implies that the cartel's profits under the mechanism equal the non-cooperative profits.

Hence, a weak cartel cannot expect to extract the full social surplus. In some cases, however, a weak cartel might be able to attain supra-non-cooperative profits. By lemma 7.3 this requires the firms to sacrifice efficiency. An example of an inefficient mechanism is bid rotation, which is a collusive agreement under which the cartel members agree to be randomly allocated to be the designated winner of the procurement auction, may improve on the non-cooperative outcome if the technological environment satisfies certain properties. More specifically, let $K(x) \equiv \frac{F(x)}{f(x)} c_\theta(q(x), x)$. Then,

Proposition 7.2. *In a weak cartel, the expected weak collusive profits $E[\pi^{WC}]$ are maximized by non-cooperative bidding if $K'(x) \leq 0$. Bid rotation is optimal if $K'(x) \geq 0$.*

Proof. The *ex ante* expected profit of firm i is

$$\begin{aligned} E[\pi_i^{WC}] &= \int_{\underline{\theta}}^{\overline{\theta}} \pi_i(t) f(t) dt \\ &= \pi_i(t) F(t) \Big|_{\underline{\theta}}^{\overline{\theta}} - \int_{\underline{\theta}}^{\overline{\theta}} \frac{d\pi_i(t)}{dt} F(t) dt \\ &= \pi(\overline{\theta}) F(\overline{\theta}) - \pi(\underline{\theta}) F(\underline{\theta}) - \int_{\underline{\theta}}^{\overline{\theta}} \frac{d\pi_i(t)}{dt} F(t) dt \\ &= \int_{\underline{\theta}}^{\overline{\theta}} a_i(t, \theta_{-i}) c_\theta(q_i(t), t) F(t) dt. \end{aligned}$$

Use integration by parts to go to the second equation, and insert the necessary condition for incentive compatibility to arrive at the third line. Industry profits can now be written as

$$E\left[\sum_{i=1}^{n} \pi_i^{WC}\right] = E\left[\sum_{i=1}^{n} \frac{F(t)}{f(t)} a_i(t, \theta_{-i}) c_\theta(q_i(t), t)\right].$$

If $K(\cdot)$ is monotonically decreasing, the industry profits are maximized by giving the largest weight to the most efficient firm. This is achieved by choosing $a_i' < 0$.

From lemma 7.3, this implies non-cooperative profits.

Now, suppose that $K(\cdot)$ is monotonically increasing. To save on notation, let $\mu_i(x)$ denote $E_{-i}[a_i(x, \theta_{-i})]$, which is firm i's expectation that it will be the designated winner, conditional on its announcement x to the mechanism. By deriving an upper bound on the industry profits, one can show that the cartel can achieve this upper bound by using a bid rotation device. The industry's profits are

$$\begin{aligned}
E\left[\sum_{i=1}^{n} \pi_i^{WC}\right] &= \sum_{i=1}^{n} \int_{\underline{\theta}}^{\overline{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t)\mu_i(t) f(t) dt \\
&\leq \sum_{i=1}^{n} \left(\int_{\underline{\theta}}^{\overline{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t) f(t) dt \cdot \int_{\underline{\theta}}^{\overline{\theta}} \mu_i(t) f(t) dt \right) \\
&= \sum_{i=1}^{n} \int_{\underline{\theta}}^{\overline{\theta}} \mu_i(t) f(t) dt \cdot \int_{\underline{\theta}}^{\overline{\theta}} \frac{F(t)}{f(t)} c_\theta(q_i(t), t) f(t) dt \\
&\leq \int_{\underline{\theta}}^{\overline{\theta}} F(t) c_\theta(q_i(t), t) dt.
\end{aligned}$$

The first inequality follows from a generalization of Chebyshev's inequality. The interested reader is referred to Sun (1996) for details. The second inequality stems from the fact that $E[\sum a_i(x, \theta_{-i})] \leq 1$. The cartel can easily obtain this bound on profits. Under a bid rotation arrangement, every firm is the designated winner with probability $1/n$. This implies that the cost parameter of the winner is drawn from the cdf $F(\theta)$. At the procurement auction, it is in the designated winner's interest to maximize its profits $p - c(q, \theta_i)$ with respect to price and quality, subject to the constraint $V(q) - p \geq 0$. Clearly, it is optimal for the firm to supply $q^*(\theta_i)$ and charge $p = V(q^*(\theta_i))$. The industry profit therefore equals

$$\begin{aligned}
E\left[\sum_{i=1}^{n} \pi_i\right] &= \int_{\underline{\theta}}^{\overline{\theta}} \left(V(q^*(t) - c(q^*(t), t)) f(t)\right) dt \\
&= \int_{\underline{\theta}}^{\overline{\theta}} F(t) \left(\frac{d}{dt} c(q^*(t), t) - \frac{d}{dt} V(q^*(t)) \right) dt.
\end{aligned}$$

From the necessary condition for profit maximization, one knows that $\frac{\partial}{\partial q} V(q^*) = \frac{\partial}{\partial q} c(q^*, \theta)$. This allows one to rewrite total profits as

$$E\left[\sum_{i=1}^{n} \pi_i^{WC}\right] = \int_{\underline{\theta}}^{\overline{\theta}} F(t) c_\theta(q^*(t), t) dt.$$

Thus, bid rotation achieves the upper bound. ■

As one can see, the above proof closely follows McAfee and McMillan's (1992) proof of their theorem 1. The proof for the two-dimensional case is stated here because it remains to show that quality is chosen optimally. Furthermore, a crucial step requires a generalization of Chebychev's inequality, a detail that McAfee and McMillan did not mention in their proof.

Again, there is an interesting parallel with the work of McAfee and McMillan (1992). In a standard auctions context, they show that if $\frac{1-F(x)}{f(x)}$ is increasing, it is optimal for a weak cartel to bid in a non-cooperative fashion. If, on the other hand, $\frac{1-F(x)}{f(x)}$ is decreasing, bid rotation is optimal. Their finding is extended to procurement auctions. In a two-dimensional auction, bid-rotation is optimal if $\frac{F(x)}{f(x)}$ increases sufficiently fast. For example, if $V(q) = \sqrt{q}$ and $c(q, \theta) = q\theta$, then bid rotation is optimal if the θ's are distributed according to the uniform distribution. On the other hand, non-cooperative play is optimal when the cost parameters are random draws from the Pareto distribution. Complementing McAfee and McMillan (1992), the above analysis shows that not only the mere distribution of types is relevant for the choice of the optimal collusive mechanism, but also the shape of the cost function. In particular, bid rotation is optimal if the cost function is sufficiently convex.

7.4.3 Strong cartels

There are many examples of bidding rings which were able to compensate losing firms. McAfee and McMillan (1992) establish that a strong cartel can extract the full *ex post* social surplus by organizing a preauction knockout (PAKT). This is an auction before the actual auction, where the firms bid for the right to be the only contender. The revenue from this auction is split evenly between the cartel members. This result carries over to the two-dimensional procurement auction.

From an *ex post* perspective, the spoils from collusion are maximized by awarding the right to be the single bidder to the most efficient firm. This firm supplies a socially optimal (and hence efficient) level of quality and charges $p = V(q^*(\theta))$. If such a mechanism exists, the *ex ante* expected cartel profits amount to

$$\begin{aligned} E\left[\sum_{i=1}^{n} \pi_i^{SC}\right] &= \int_{\underline{\theta}}^{\overline{\theta}} \pi(t) nF(t)(1-F(t))^{n-1} dt \\ &= \int_{\underline{\theta}}^{\overline{\theta}} \left(V(q^*(t)) - c(q^*(t), t)\right) nF(t)(1-F(t))^{n-1} dt, \end{aligned} \tag{7.10}$$

where $nF(t)(1-F(t))^{n-1}$ is the probability density function of the first-order statistic. Consider a PAKT where firms non-cooperatively and simultaneously submit a sealed bid T_i. The highest bidder i pays every other firm T_i and all other firms commit to stay away from the actual procurement auction (or to submit phony bids). It is straightforward to show the following.

Proposition 7.3. *The symmetric equilibrium bid function at the PAKT is*

$$T(\theta) = \int_{\theta}^{\overline{\theta}} \frac{(1-F(t))^{n-1}}{(1-F(\theta))^{n}} \left(V(q^*(t),t) - c(q^*(t),t)\right) f(t)dt.$$

The winning firm submits an uncontested bid at the procurement auction that extracts the full social surplus and pays every losing bidder $T(\theta)$. This mechanism is efficient, achieves budget balance, and maximizes cartel profits.

Proof. To derive the equilibrium bid function, suppose that in the PAKT, $n-1$ firms truthfully submit their bid using $T(\theta)$ and $T'(\theta) < 0$. Firm i submits a bid as if its cost parameter is x. Then, the expected profit of firm i is

$$H(x)(V(q^*(\theta)) - c(q^*(\theta),\theta_i) - (n-1)T(x)) - \int_{\underline{\theta}}^{x} T(y)h(y)dy.$$

The first-order condition, evaluated in $x = \theta_i$, implies that

$$\frac{h(\theta)}{H(\theta)}T'(\theta_i) + \frac{n}{n-1}T(\theta) = \frac{V(q^*(\theta)) - c(q^*(\theta),\theta_i)}{n-1}.$$

This is a linear first-order differential equation with variable coefficients. Using $e^{\left(\int_{\underline{\theta}}^{\theta} \frac{n}{n-1}\frac{h(t)}{H(t)}dt\right)}$ as the integrating factor and noting that $T(\overline{\theta}) = 0$, the solution can be shown to be

$$T(\theta) = \int_{\theta}^{\overline{\theta}} \frac{(1-F(t))^{n-1}}{(1-F(\theta))^{n}} \left(V(q^*(t),t) - c(q^*(t),t)\right) f(t)dt.$$

To prove the other claims in the proposition, note that $T'(\theta) < 0$. Hence, efficient firms submit higher bids than inefficient firms and therefore the most efficient firm in the cartel is the designated winner of the procurement auction. Budget balance is trivially achieved because the scheme divides the full social surplus between all cartel members. Cartel profits are maximized as the most efficient firm is selected, this firm extracts the full social surplus, and transfers a fraction of this surplus to every other cartel member. ■

The PAKT allows firms to obtain the maximum possible profits, as given by equation (7.10), because it is efficient and the government receives zero utility. As mentioned above, McAfee and McMillan (1992) find a similar result for a one-dimensional first-price auction. The fact that a PAKT also enables firms to maximize profits for a two-dimensional procurement auction, suggests that a PAKT is an optimal collusive mechanism for more general environments.

Given that a PAKT is optimal in quite general environments, it should not come as a surprise that many real-world cartels have relied on agreements that are similar to a PAKT. Even without knowledge of the rather intricate details of mechanism design, many cartels have figured out how to optimally collude. For example, the cast-iron-pipe cartel (1894–1898), which is the first cartel convicted under the Sherman Act[5], used a mechanism similar to a PAKT, see Orr and MacAvoy (1965). There are strong indications that the Dutch construction cartel operated under a PAKT as well. The interested reader is referred to the report of the parliamentary inquiry commission for an extensive description of this cartel (The Vos Committee, 2002).

7.5 Coping with collusion

The collusive mechanisms studied in this chapter have important implications for the government. Both a weak cartel and a strong cartel leave the government with zero utility. A weak cartel has the additional drawback that it is inefficient. Since government projects are typically financed by means of distortionary taxation, decreasing the impact of collusion should be a top priority.

There are several ways to do this. An emerging strand of literature, initiated by Motta and Polo (2003), focuses on the use of optimal fines and leniency programs to destabilize cartels. By punishing cartel members and awarding fine reductions to firms who self-report, a cartel may break down. A leniency policy is a general method to destabilize cartels and is applicable in many other markets besides auctions.

Another approach, which is more specific to auctions, is suggested by McAfee and McMillan (1992). They propose that the auctioneer can actively meddle with the collusive mechanism. If the auctioneer suspects that firms have formed a bidding ring, for instance, he could commit to bargain with a single firm. This instantly breaks down the cartel (as there is just one firm active) and leaves the auctioneer with a positive surplus.[6] Another way in which the government can interfere with the collusive mechanism is by being vague about the government's valuation for

[5] Addyston Pipe and Steel Co. v. United States, 85 F. 271,(1898).

[6] See the following chapter for a comparison of negotiations and auctions in the presence of a cartel.

quality. That is, the government does not resolve any uncertainty among the firms about $V(q)$. This might make it harder for the firms to find the optimal collusive price and creates a need for communication between firms. Given that communication between firms can be intercepted by the anti-trust authority, this strategy makes collusion more costly to the firms.

The third approach, and the one pursued below, consists of changing the auction rules. More specifically, the government may announce (and commit to) a reservation utility, which means that only bids that yield the government at least a minimum utility level are eligible. The first-score auction is a special case of the reservation utility auction, as it requires firms to submit bids that leave the government with at least zero utility. Even if firms coordinate their bids, the reservation utility auction guarantees at least a positive expected utility. The section below derives the optimal reservation utility auction. This auction maximizes the government's surplus, given the presence of a bidding ring.

7.5.1 The reservation utility auction

Suppose that the government commits to a reservation utility $\overline{U} \geq 0$ and the firms collude by organizing a PAKT. Then, the cartel's designated winner clearly chooses to leave the government with the lowest possible utility, which is $\overline{U}$. The profit of the selected firm is, after substituting for the price, $\pi = V(q) - c(q,\theta) - \overline{U}$. As $\overline{U}$ is constant, the selected firm offers the quality level $q^*(\theta)$ that maximizes social surplus, given θ.

If $\overline{U} > 0$, some relatively inefficient firms are excluded. In particular, all firms with type above $\hat{\theta}$ are unable to supply the minimum utility level, where $\hat{\theta}$ is implicitly (and uniquely) defined by $V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}),\hat{\theta}) = \overline{U}$. The problem for the government is to choose $\overline{U}$ such that

$$\begin{aligned} E[U] &= \Pr(\theta < \hat{\theta})\overline{U} \\ &= (1-(1-F(\hat{\theta}))^n)\overline{U} \\ &= (1-(1-F(\hat{\theta}))^n)(V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}),\hat{\theta})) \end{aligned} \tag{7.11}$$

is maximized. To go from the first to the second line, note that the distribution of θ is the distribution of the lowest-order statistic since the firms use a PAKT. To arrive at the third equation, substitute $\overline{U}$ for $V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}),\hat{\theta})$. So, the government can indirectly find the optimal $\overline{U}$ by choosing $\hat{\theta}$ optimally. The first-order condition is

$$\frac{1-(1-F(\hat{\theta}))^n}{nf(\hat{\theta})(1-F(\hat{\theta}))^{n-1}} = \frac{V(q^*(\hat{\theta})) - c(q^*(\hat{\theta}),\hat{\theta})}{c_\theta(q^*(\hat{\theta}),\theta)}. \tag{7.12}$$

Then,

Proposition 7.4. *Suppose firms collude by using a PAKT. Then, the optimal reservation utility $\overline{U}$ is unique if $F(\cdot)$ is log-concave.*

Proof. Clearly, $\overline{U}$ is unique if $\hat{\theta}$ is unique. There is a unique solution of (7.12) if $F(\theta)$ is log-concave. To see this, observe that the right-hand side of (7.12) is positive for $\underline{\theta}$ (because social surplus is positive for the most efficient type) and is strictly decreasing in θ (because social surplus strictly decreases as the firm becomes less efficient). The left-hand side is zero for $\underline{\theta}$, one for $\overline{\theta}$ and increases monotonically if $F(\theta)$ is log-concave. ■

Log-concavity implies $f(x)^2 - F(x)f'(x) \geq 0$. Many 'named' probability distributions satisfy this property, including the uniform, the exponential, and the normal distribution. See Bagnoli and Bergstrom (2005) for an extensive discussion of log-concavity. Interestingly, log-concavity also implies that the mechanism design problem is regular.

It is straightforward to show that proposition 7.4 can be extended to the case where firms collude by using a bid-rotation mechanism. In that case, the efficiency parameter of the selected firm is drawn from $F(\theta)$, conditional on $\theta < \hat{\theta}$.

7.5.2 Minimum quality, maximum price

Despite its theoretical appeal, few government agencies seem to use the reservation utility auction. Presumably, an important obstacle that hinders its actual implementation is that in reality the way in which quality is valued is asymmetrically (and often imperfectly) known by the government and very costly to communicate to the firms. Moreover, it may be very hard to describe $\overline{U}$ in a contract such that a court can enforce it.

To circumvent these problems, government agencies typically revert to simpler procurement auction formats. For instance, a government agency could award the contract to the firm that offers the highest utility, but require that the price does not exceed a maximum price P and entails at least a minimum quality level Q. To save some space, call an auction format with these rules a PQ auction.

It is easy to see that in the first-score auction, P is set at ∞ and Q is zero. Suppose the government uses a PQ auction with a finite maximum price P and positive quality level Q. Then, if the firms collude by using a PAKT, the selected firm offers the good at the maximum price with the lowest possible quality level. This implies that the PQ auction, in contrast to the reservation utility auction, yields productive inefficiency: the firm's quality decision does not maximize social surplus. Just as under the reservation utility auction, however, some inefficient firms are excluded. All firms with efficiency parameter θ above $\tilde{\theta}$, where $\tilde{\theta}$ is implicitly defined by $P - c(Q, \tilde{\theta}) = 0$, are unwilling to provide the good.

To maximize its expected utility under this auction format, the government chooses P and Q to maximize

$$E[U] = \Pr(\theta < \tilde{\theta})(V(Q) - P). \tag{7.13}$$

It is not difficult to demonstrate that an optimal reservation utility auction yields a higher expected utility level than a PQ auction where P and Q are optimally chosen. Suppose that both auction formats require the same utility from the firm with type θ that is selected by the cartel. Then, $\overline{U} = V(q^*(\theta)) - c(q^*(\theta), \theta) = V(Q) - P$. Assuming that $\theta > \hat{\theta}$ and $\theta > \tilde{\theta}$, the profit for the designated winner under the reservation utility auction is

$$\begin{aligned}
\pi(\theta) &= p - c(q^*(\theta), \theta) \\
&= V(q^*(\theta)) - c(q^*(\theta), \theta) - \overline{U} \\
&> V(Q) - P,
\end{aligned}$$

where the inequality follows from the definition of $q^*(\theta)$. Thus, keeping $\overline{U}$ constant, the profit of a firm under the reservation utility auction is higher than the profit under the PQ auction. This implies that $\hat{\theta}$ (the shut-down type in the reservation utility auction), is smaller than $\tilde{\theta}$ (the shut-down type in the PQ auction). This means that the expected utility for the government is necessarily higher under the reservation utility auction because the probability that a firm is unable to supply is lower. The next proposition summarizes this finding.

Proposition 7.5. *Suppose firms collude by sending a single firm to the procurement auction. Then, the reservation utility auction yields a higher expected utility to the government than the PQ auction.*

Therefore, the reservation utility auction is superior to the PQ auction in terms of the expected utility they garner when firms collude. This results holds both when the firms use a PAKT and when they use a bid-rotation mechanism.

7.5.3 Deterring collusion

The reservation utility auction helps the government to lower the costs of collusion. It may even allow the government to deter collusion altogether, as the analysis in this section shows.

Equation (7.12) characterizes the unique optimal reservation utility $\overline{U}$ if firms collude. Call this solution $\overline{U}^K$. It should be clear that in this case the optimal reservation utility (call it $\overline{U}^N$) differs from $\overline{U}^K$. This is because a cartel member offers a price and quality such that the government just obtains $\overline{U}^K$. A non-cooperative firm cannot afford to do this. It is subject to competition from other firms and therefore offers a higher utility than $\overline{U}^N$. As can be shown using standard tricks, a non-cooperative firm offers a quality level $q^*(\theta)$ and charges a price

$$\hat{p}(\theta) = c(q^*(\theta),\theta) + \int_{\theta}^{\hat{\theta}} \frac{H(t)}{H(\theta)} c_\theta(q^*(\theta),\theta)dt. \tag{7.14}$$

The government's expected utility under non-cooperative bidding is

$$E[U] = n \int_{\underline{\theta}}^{\hat{\theta}} \left[V(q^*(\theta)) - \hat{p}(\theta)\right] (1 - F(\theta))^{n-1} f(\theta) d\theta. \tag{7.15}$$

The optimal reservation utility level under non-cooperative behavior is characterized by

$$\frac{F(\hat{\theta})}{f(\hat{\theta})} = \frac{V(q^*(\hat{\theta}),\hat{\theta}) - c(q^*(\hat{\theta}),\hat{\theta})}{c_\theta(q^*(\hat{\theta}),\hat{\theta})}. \tag{7.16}$$

Again, the optimal $\hat{\theta}$, and therefore the optimal $\overline{U}^N$, is uniquely defined if $F(\theta)$ is log-concave.

The government's response, $\overline{U}$, is affected by the firms' decision to cartelize. The government commits to $\overline{U}^N$ if firms do not collude, and to $\overline{U}^K$ if they collude by using a PAKT. Clearly, changes in $\overline{U}$ affect firms' expected profits. It may even be possible that the firms' expected profits under collusion are lower than under competition, once the government commits to the optimal reservation utility level.

To show this formally, consider the following timing of events. First, firms decide whether they form a bidding ring. If one or more firms decide not to join the ring, all firms act non-cooperatively at the procurement auction. Second, the government observes the cartel decision of the firms (but cannot notify the anti-trust authorities) and commits to a reservation utility. Third, the cartel members or the non-cooperative firms submit bids and the contract is awarded according to the rules of the reservation utility auction.

The assumptions about the timing of events seems to be fairly realistic. In practice, the government agency designs a procurement process, given the expected behavior of firms. Firms form a cartel only if the expected benefits outweigh the expected costs. See Thomas (2005) for a study of optimal reserve prices in the presence of collusion in first-price one-dimensional auctions that employs the same assumptions about timing.

It is impossible to compare profits for the general case. Therefore, consider the following parametric assumptions: $V(q) = q$, $c(q, \theta) = \theta q$ and θ is drawn from $U(0, 1)$.

n	$100 * E[\pi^N]$	$100 * E[\pi^K]$	n	$100 * E[\pi^N]$	$100 * E[\pi^K]$
1	4.321	4.321	8	0.996	0.988
2	3.395	3.125	9	0.808	0.868
3	2.695	2.400	10	0.717	0.770
4	2.163	1.918	11	0.616	0.688
5	1.754	1.589	12	0.534	0.620
6	1.437	1.328	13	0.476	0.562
7	1.190	1.137	14	0.411	0.513

Table 7.1. Profits under Competition and Collusion

Table 7.1 shows the expected profits per firm, both under non-cooperative and collusive behavior. For $n \geq 8$, firms expect higher profits if they can commit to non-cooperative behavior. Hence, collusion lowers firms' profits if their number is relatively small and the government optimally responds to the presence of a cartel.

Consistent with McAfee and McMillan (1992) and Thomas (2005), these results suggest that the government has the tools to mitigate the effects of collusion or to even deter it. However, the optimal tool differs in a two-dimensional setting. Instead of a reserve price, the government should commit to a reservation utility. In practice, this could be implemented by using a scoring rule auction, and requiring that the winning offer attains at least a minimum score. See Dini, Pacini and Valletti (2006) for a discussion of scoring rules. In practice, scoring rules are used to rank multidimensional bids. The message of this chapter is that scoring rules can be an anti-collusive device.

7.6 Concluding remarks

Ample anecdotal, legal, and empirical evidence shows that firms collude in public procurement. To study collusion in procurement, Che's (1993) model of multidimensional auctions is extended McAfee and McMillan's (1992) results on collusion. Interestingly, in contrast to the optimal mechanism (from the cartel's perspective), collusion does not distort the quality decision of the firms, but does reduce the government's expected utility to zero.

To lower the costs of collusion, or even to deter it, the government can try to commit to a reservation utility auction. It is shown that this auction format enables the government to capture a large fraction of the social surplus, even in the presence of collusion. Using simple arguments, it is demonstrated that the reservation utility auction is a better instrument to mitigate the costs of collusion than the commonly used (and advocated) auction with a reserve price and a minimum quality level. Finally, using a parametric example, the anti-collusive effect of the reservation utility auction is demonstrated. This suggests that procurement agencies could profitably procure goods or services by using an auction with a scoring rule, combined with a minimum score requirement.

Chapter 8

Auctions vs. negotiations with asymmetric or colluding buyers

8.1 Introduction

When an owner of a valuable asset decides to sell his property he may conduct an auction to maximize his expected profits, but there are alternative mechanisms. In practice, a seller (or, in a procurement context, a buyer) often reverts to negotiations with a single buyer.[1] The use of negotiations is puzzling, as Bulow and Klemperer (1996) (BK henceforth) have shown that auctions tend to yield more revenue than negotiations. More precisely, they demonstrate that an English auction without a reserve price and $n+1$ buyers generates more revenue than the optimal mechanism (assuming the seller has superior bargaining skills) with n buyers. This suggests that revenue-maximizing sellers should direct attention at expanding the set of buyers instead of designing 'clever' negotiation procedures.

The aim of this chapter is to understand why some sellers still prefer negotiations over auctions. To do so, the analysis of BK is adjusted in three directions. First, the seller is allowed to have better information than buyers, in the sense that a seller knows the value of each buyer whereas the buyers only know their own value and perceive the value of each other buyer as being randomly drawn from some probability distribution. Then, with a superiorly informed seller, BK's reve-

[1] Examples include public procurement officials or boards of directors involved in the takeover of their company. See Significant B.V. (2005) for an overview of the practice of public procurement in the Netherlands. They report that procurement agencies are reluctant to comply with European procurement guidelines, which stipulate that large projects should be publicly tendered. Boone and Mulherin (2007) study the market for corporate takeovers. They find that about 50% of corporate acquisitions are accomplished through auctions and the other half through negotiations.

nue ranking is shown to be reversed. Second, buyers are often asymmetric. In a European Union-wide public procurement process, as an example, the costs of a domestic firm are likely to be drawn from a very different distribution than the costs of a foreign firm. Third, the buyers are assumed to coordinate their behavior in a bidding ring. Asymmetry and collusion turn out to have similar effects. BK's revenue ranking remains intact if the buyers are not too asymmetric or the cartel is not too large.

This chapter continues with a quick review of BK's result in section 8.2.1. BK assume that the seller is uninformed about the realization of the values of the buyers. In section 8.2.2 the effect of an informed buyer in considered. The "auction vs. negotiation" result is reconsidered for asymmetric buyers and colluding buyers in section 8.3 and 8.4, respectively. Section 8.5 offers some final remarks.

8.2 The symmetric benchmark

8.2.1 An uninformed seller

A seller owns an indivisible object and may sell it to one of $n \geq 1$ symmetric buyers. The seller's value for the object is normalized to zero, and the buyers' values are drawn independently from a common cumulative distribution function F with support $[0, v]$.[2] Buyers privately observe their value and are uninformed about the realization of the other values. F is continuously differentiable and has a positive density on its entire support. Additionally, the *virtual valuation* $\phi(u) \equiv u - \frac{1-F(u)}{f(u)}$ increases in u. This assumption guarantees that the seller's mechanism design problem is regular. In the present context, regularity implies that it is optimal to set a reserve price and allocate the object to the highest bidder. Each buyer is privately informed about its value before the auction or mechanism takes place. The seller and the buyers are risk-neutral and aim to maximize expected payoffs.

From the theory of mechanism design, it is well-known that the seller can extract at most

$$\Pi_N = E[\max\{\phi_1, \phi_2, \ldots, \phi_n, 0\}] \tag{8.1}$$

from the buyers. The subscript N refers to negotiations and ϕ_i is the virtual valuation of buyer i. See Myerson (1981) for the seminal contribution to mechanism

[2] This chapter restricts attention to the private values framework. BK study auctions and negotiations in a more general interdependent values setting.

design and Krishna (2002) for a recent introduction. This places an upper bound on the revenue the seller may expect from negotiations. In fact, the seller is likely to obtain much less revenue from negotiations. This is because the seller is unlikely to hold all bargaining power, as mechanism design theory presupposes. Furthermore, he may not be able to commit to actions that are dominated *ex post*.

The seller may also allocate the object by means of an absolute English auction. This is an auction without a reserve price in which the price continuously increases until all but one bidder have dropped out. By the assumption that buyers are symmetric and that virtual valuations are increasing, the revenue of the auction can be written as

$$\Pi_{EA} = E[\max\{\phi_1, \phi_2, \ldots, \phi_n\}], \tag{8.2}$$

where the subscript EA refers to English auction. This is clearly, and by definition, lower than the revenue from the optimal mechanism. However, BK show that with just one additional buyer, the revenue of the absolute English auction is strictly larger than the revenue of negotiating with the former set of buyers.

Proposition 8.1 (Bulow and Klemperer, 1996)**.** *An absolute English auction with $n+1$ buyers yields more expected revenue than any negotiation with n buyers.*

Proof. The proof follows Krishna (2002). It is obvious that the auction dominates the optimal mechanism if $\max\{\phi_1, \ldots, \phi_n\} > 0$. Therefore, suppose that $\max\{\phi_1, \ldots, \phi_n\} < 0$. Then,

$$\begin{aligned}
&E[\max\{\phi_1, \ldots, \phi_n, \phi_{n+1}\} \mid \max\{\phi_1, \ldots, \phi_n\} < 0] \\
&\quad > \max\{E[\phi_1 | \phi_1 < 0], \ldots, E[\phi_n | \phi_n < 0], E[\phi_{n+1}]\} \\
&\quad = \max\{E[\phi_1 | \phi_1 < 0], \ldots, E[\phi_n | \phi_n < 0], 0\} \\
&\quad = 0 \\
&\quad = E[\max\{\phi_1, \ldots, \phi_n, 0\} \mid \max\{\phi_1, \ldots, \phi_n\} < 0].
\end{aligned}$$

The inequality follows from Jensen's inequality and the fact that "max" is a convex function.[3]

Hence, the auction is also superior if $\max\{\phi_1, \ldots, \phi_n\} < 0$ and the result follows.

[3] To see this, note first that a function $f(\mathbf{x}) = f(x_1, x_2, \ldots, x_n)$ is convex if $\lambda f(\mathbf{x}) + (1-\lambda) f(\mathbf{y}) \geq f(\lambda \mathbf{x} + (1-\lambda)\mathbf{y})$ for all $\mathbf{x}$ and $\mathbf{y}$ in the domain of f and all λ in $(0,1)$. Suppose without loss of generality that $x_1 \geq x_2 \geq \ldots \geq x_n$. Then, $\max\{\mathbf{x}\}$ is convex if $\lambda x_1 + (1-\lambda)\max\{\mathbf{y}\} \geq \max\{\lambda \mathbf{x} + (1-\lambda)\mathbf{y}\}$. By assumption, $\lambda x_1 + (1-\lambda)\max\{\mathbf{y}\} \geq \max\{\lambda \mathbf{x} + (1-\lambda)\mathbf{y}\}$ and a sufficient condition for convexity is therefore $\lambda x_1 + (1-\lambda)\max\{\mathbf{y}\} \geq \lambda x_1 + (1-\lambda)\max\{\mathbf{y}\}$. This weak inequality is exactly met.

■

The common interpretation of proposition 8.1 is that competition is more valuable than negotiations. A revenue-maximizing seller is better off by spending resources to enlarge the number of buyers, than to find the optimal mechanism.

Krishna's (2002) proof of proposition 8.1 is used here mainly because of its elegance. However, it may be instructive to discuss an alternative proof. In a recent contribution, Kirkegaard (2006) offers an intuitive interpretation of BK's result. Consider the revenue of the optimal mechanism, Π_N, with n buyers. With $n+1$ buyers, the seller can easily obtain the same revenue by applying the optimal mechanism to the first n buyers, and give the object for free to the $(n+1)^{th}$ buyer if the object was not allocated under the optimal mechanism. This mechanism always allocates the object to a buyer. However, the seller can do even better by conducting an absolute English auction. This is because the absolute English auction is the optimal mechanism to allocate an object, subject to the condition that the object must be allocated.

8.2.2 An informed seller

BK assume that the revenue of negotiations is bounded by the expected revenue of the optimal mechanism. This assumption implicitly supposes that the seller is equally informed about the value of any given buyer as each other buyer. In many important settings, this common prior assumption seems to be justifiable. For instance, buyers and sellers on the market of collectible items frequently interact, regularly change positions (a buyer today could be a seller tomorrow), and have similar sophisticated information about the value of items.

In other settings, however, it may be more realistic to assume that the seller has better information about the values than the buyers. This might apply to the housing market or the market for second-hand cars. In these markets, sellers trade frequently with inexperienced buyers. The large number of trades enables sellers to predict the values of potential buyers. For instance, the value of a potential buyer of a car might be correlated with observable characteristics, like the size of the buyer's family, the buyer's current car, or whether the buyer owns a dog. Other potential buyers are less capable of estimating a buyer's value because they lack the seller's experience.

The simplest way to incorporate the idea that the seller has superior information, is to suppose that the seller *knows* the buyers' values. The buyers still consider the value of any given buyer as an independent draw from F. By making a take-it-or-leave-it offer to the buyer with the highest value, the seller can extract the entire surplus. The (expected) revenue is simply the (expected) highest value. Call this mechanism *perfect negotiations*.

The obvious question is whether BK's revenue ranking extends to perfect negotiations. The answer is no.

Lemma 8.1. *Perfect negotiations with n buyers generate more revenue than an absolute English auction with $n+1$ buyers.*

Proof. Perfect negotiations are superior to auctions for any realization of the values. Let x be the highest value among n buyers, and y the highest value among $n+1$ buyers. The revenue of perfect negotiations is x. First, notice that for $y > x$ the auction yields a revenue of x. This is because the winner of the auction, which is the additional buyer, pays the second-highest bid, x. For $x > y$, the winner is among the first n buyers and pays less than x. Hence, the revenue of the auction is bounded by x, and strictly lower with positive probability. ■

This result turns BK's revenue ranking around. An informed seller would *never* find it optimal to invite an additional buyer and let an English auction determine the price.

One could conjecture that lemma 8.1 follows from the fact that in an English auction buyers have a dominant strategy to bid their own value. This implies, as the proof demonstrates, that the revenue of the auction is bounded by the revenue of negotiations for any realization of the values. Alternative auction formats may not have this property. However, a simple application of the Revenue Equivalence Principle shows that lemma 8.1 extends to a comparison of perfect negotiations and any standard auction format.[4, 5]

Proposition 8.2. *Perfect negotiations with n buyers generate more revenue than any symmetric and increasing equilibrium of any absolute standard auction with $n+1$ buyers.*

Proposition 8.2 generalizes lemma 8.1. Given that the seller has perfect information, he prefers negotiations with n buyers over a simple auction with $n+1$ buyers. Under the assumption that the seller is uninformed, BK obtain the exact opposite

[4] Krishna (2002) defines a standard auction as an auction whose rules dictate that the buyer who bids the highest amount is awarded the object.

[5] In the discussion of their main result, BK anticipate this result. However, they do not derive it formally and do not discuss its implications.

result. BK derive an upper bound on the value of mechanism design, whereas proposition 8.2 provides an upper bound on the value of competition. This helps to understand not only the limitations of BK's result, but also institutional characteristics of particular markets. For instance, proposition 8.2 may explain why houses and second-hand cars are predominantly sold via negotiations, and government bonds and art via auctions.

Admittedly, proposition 8.2 applies only to environments where buyers have private values. An open question is how this result can be generalized to buyers with interdependent values.

8.3 Asymmetric buyers

Introducing an informational asymmetry between the seller and buyers upturns BK's result. *Ex ante* asymmetry may also arise between buyers.[6] In many important settings, such as public procurement or corporate takeovers, asymmetry appears to play a crucial role. The first firm to enter a procurement process, for instance, is likely to have a lower cost of providing the good than the second firm. This section discusses the effects of asymmetry between buyers on BK's revenue ranking.

To keep the analysis tractable, restrict the number of buyers to two and assume that values of the buyers are drawn from the power function distribution with support $[0,1]$. The value of the first buyer is drawn from x^α and the second buyer's value is drawn from y^β. The exponent of the distribution functions indicates the strength of a buyer. Buyer 1 is called strong if $\alpha > \beta$ and weak otherwise. Suppose that $\alpha \geq 1$. This restriction ensures that the mechanism design problem is regular

As before, the revenue of the optimal mechanism is $E[\max\{\phi_1, 0\}]$. This can be written as

$$\begin{aligned}
\Pi_N &= \Pr\left(x - \frac{1-x^\alpha}{\alpha x^{\alpha-1}} > 0\right) E\left[x - \frac{1-x^\alpha}{\alpha x^{\alpha-1}} \Big| x > \frac{1-x^\alpha}{\alpha x^{\alpha-1}}\right] \\
&= \frac{\alpha}{\alpha+1} E\left[x - \frac{1-x^\alpha}{\alpha x^{\alpha-1}} \Big| x > \left(\frac{1}{1+\alpha}\right)^{1/\alpha}\right] \\
&= \alpha(\alpha+1)^{\frac{\alpha+1}{\alpha}}. \qquad (8.3)
\end{aligned}$$

Suppose the seller has the opportunity to invite another potential buyer and conduct an absolute English auction. Let F and G be the cumulative distribution func-

[6] Clearly, there exists an *ex post* asymmetry between buyers in the private values model since buyers do not know each others' values.

tions of the values of the first and second buyer. Then, expected revenue can be written as

$$\Pi_{EA} = \int_0^v (1 - F(u))ug(u)du + \int_0^v (1 - G(u))uf(u)du.$$

For the power function distribution, this simplifies to

$$\Pi_{EA} = \frac{\alpha\beta(2 + \alpha + \beta)}{(1 + \beta)(1 + \alpha + \beta)}. \tag{8.4}$$

Suppose $\alpha = 1$. Then, the auction is revenue superior if and only if $\beta > -\frac{3}{2} + \frac{1}{2}\sqrt{17} \approx 0.562$. Hence, BK's result holds if the additional buyer is not too weak. This insight applies more generally. The English auction is revenue superior if and only if

$$\frac{\beta(2 + \alpha + \beta)}{(1 + \beta)(1 + \alpha + \beta)} - (1 + \alpha)^{-1/\alpha} > 0. \tag{8.5}$$

It is not hard to show the following.

Proposition 8.3. *There exists a unique β such that for any finite α, the absolute English auction with two buyers yields more expected revenue than any negotiation with one buyer.*

Proof. For $\beta = 0$, a non-serious additional buyer, the optimal mechanism yields a higher revenue than the auction. As β increases, the expected revenue of the auction increases monotonically. In the limit, as β becomes arbitrarily large, the auction dominates negotiations because the price paid by the winner of the auction is the value of the first buyer. As a result, there is a unique β for which the auction and negotiations yield the same revenue. ■

The seller prefers the English auction over any negotiation if the second buyer is sufficiently strong. This extends BK's revenue ranking to asymmetric buyers and uncovers an important restriction of the validity of BK's analysis. In the concluding remarks, BK argue that "a firm that refused to negotiate with a potential buyer, and instead put itself up for auction, should be presumed to have exercised reasonable business judgment.". The result of proposition 8.3 substantially weakens this assertion.

One could object, however, that proposition 8.3 states the obvious. BK's result is valid for symmetric buyers and, by continuity, remains valid if the additional buyer is not too weak. It may be more important to understand *how* weak the additional buyer is allowed to be.

To address this critique, notice first that the explicit solution for Π_N and Π_{EA} can be used to check whether the additional buyer is strong enough for any α and β. Second, $\bar{\beta}(\alpha)$, which is the lowest β for which (8.5) holds, is strictly lower than α. This is because (8.5) holds for $\alpha = \beta$ and, by continuity, also if β is slightly lower. Third, it is easy to show that $\frac{\partial}{\partial \alpha}\bar{\beta}(\alpha) < 1$. This implies that, as the first buyer becomes stronger, the additional buyer needs to be relatively less strong.

8.4 Colluding buyers

Buyers may cooperate and form a cartel of buyers, also known as a bidding ring. The presence of bidding rings has been documented in various industries and, according to some observers, bidding rings almost always plague auctions. Even if firms are *ex ante* symmetric, the formation of an incomplete bidding ring creates asymmetries between ring-members and outsiders. This section studies the effect of a bidding ring on the value of competition.

Suppose the initial $n \geq 1$ buyers have formed a bidding ring, of the type described in Graham and Marshall (1987). Then, the bidding ring sends the buyer with the highest value to the negotiations. This implies that the seller faces a buyer whose value is drawn from $F(u)^n$. For tractability, assume that individual buyers draw their value from the uniform distribution on the unit interval. Then, by relabeling (8.3), the revenue of the optimal mechanism can be written as

$$\Pi_N = n(n+1)^{\frac{n+1}{n}}. \tag{8.6}$$

Instead of inviting one additional buyer, as BK assume, suppose that the seller may invite k additional buyers and run an absolute English auction. Assume that the new buyers do not join the ring or collude themselves. (Otherwise, the auction yields zero revenue to the seller.) To derive the revenue of the English auction, note that if the cartel's nominee wins the auction, he expects to pay the maximum value among the non-colluding buyers. This implies that, for a general common distribution function F, the expected payment of the nominee when his value is x is

$$M(x) = \int_0^x u dF(u)^k. \tag{8.7}$$

The *ex ante* expected payment, i.e. before the nominee learns his value, is simply

$$E[M] = \int_0^v u(1 - F(u)^n) dF(u)^k. \tag{8.8}$$

Given that the nominee's value is x, the representative new buyer's value is y_i, and $y_i > x$, buyer i expects to pay

$$\begin{aligned} m_i(x, y_i) &= \Pr(x > \max\{y_{-i}\})\, x \\ &\quad + \Pr(x < \max\{y_{-i}\} < y_i)\, E[\max\{y_{-i}\} < y_i] \\ &= F(x)^{k-1} x + \int_x^{y_i} u dF(u)^{k-1}. \end{aligned}$$

By integrating over x and y one obtains the new buyer's *ex ante* expected payment

$$E[m] = \int_0^v (1 - F(u)) F(u)^{k-1} u d(u)^n + \int_0^v (1 - F(u)) F(u)^n u dF(u)^{k-1}. \tag{8.9}$$

The revenue of the English auction is simply $E[M] + kE[m]$. For the uniform distribution, this becomes

$$\Pi_{EA} = \frac{k(n + k^2 + 2kn + n^2 - 1)}{(k+1)(n+k)(n+k+1)}. \tag{8.10}$$

Does the presence of collusion destroy BK's revenue ranking? To answer this question, consider first a bidding ring of two buyers ($n = 2$). In that case, as is straightforward to verify by comparing Π_N and Π_{EA}, just one additional buyer is sufficient to ensure that the auction yields more revenue. So, even if a seller faces an all-inclusive cartel in negotiations, inviting just one extra buyer and hold an auction instead more than offsets the loss in bargaining power.

Just as with asymmetric non-cooperative buyers, the English auction generates more revenue if the number of additional (non-cooperative) buyers is sufficiently large.

Proposition 8.4. *There is a unique number of buyers k such that for every bidding ring with n buyers the absolute English auction with $n + k$ members raises more revenue than any negotiation with the bidding ring.*

Proof. For $k = 0$, the English auction yields zero revenue, and is therefore dominated by negotiations. As k goes to infinity, the revenue of the English auction converges to 1, which is strictly above Π_N. Finally, since the revenue of the English auction with $n + k$ buyers increases in k, there is a unique k such that $\Pi_N = \Pi_{EA}$. ∎

Similar to the case of asymmetric buyers, collusion among buyers does not imply that additional buyers are less valuable than the optimal mechanism. Negotiations with a small bidding ring are less profitable to the seller than an English auction with a relatively large group of outsiders. To understand *how* large the number of outsiders should be, consider the ratio $\bar{k}(n)/n$, where $\bar{k}(n)$ is the (unique) solution of $\Pi_N(k) = \Pi_{EA}(k)$. It is straightforward to show that $\bar{k}(1)/1$ is $2/3$. Moreover, $\bar{k}(n)/n$ decreases in n. Hence, for any bidding ring, the number of outsiders is *at most* $2/3$ of the number of cartel members.

Two caveats. When a bidding ring exists, foregoing the ability to negotiate may be very costly, irrespective of the number of additional buyers. First, the new buyers may collectively join the ring, extracting all surplus from the seller. Second, switching from negotiations to an auction may actually *induce* collusion, because, as Robinson (1985) noted, collusion in an English auction is one-shot stable.

8.5 Concluding remarks

This chapter complements BK's upper bound on the value of mechanism design with an upper bound on the value of competition. This new upper bound helps to explain why in many environments sellers prefer negotiations over auctions. In particular, a seller who possesses better information about the value of a buyer than any other buyer is better off by relying on negotiations to maximize revenue.

There are more reasons why a seller may prefer negotiations over auctions. Large asymmetries between buyers tilts the scale in favor of negotiations, as do bidding rings. The underlying reason why BK's revenue ranking of auctions and negotiations fails in these two cases is the same. In negotiations, the seller is able to extract (through a take-it-or-leave-it-offer) the buyer's or ring's large expected value. In a simple auction without a reserve price he is unable to exploit his knowledge of one buyer's or ring's large willingness-to-pay.

In view of the general theme of this thesis, collusion, this chapter's main insight is that in the presence of a cartel a seller may respond by changing the selling format. This is more drastic than the policy recommendations in chapters 6 and 7, which concluded that an auctioneer may adapt the auction rules in response to collusion. The analysis in this chapter advises to abandon the auction altogether in certain special cases.

Chapter 9

Conclusion

11.

George J. Stigler (1977, p. 442)

9.1 Summary

Many countries, including Germany, the United Kingdom and the United States, have adopted antitrust (or competition) laws that prohibit firms to enter into agreements that are potentially harmful to society at large. Acts that are considered to be illegal include horizontal mergers that create a monopoly and price agreements. Although such laws have been in place for many years (the U.S. Sherman Act dates from 1890) and are uncontroversial among most economists and policymakers,[1] there are still many open questions. The essays in this thesis apply game-theoretic tools to formulate and answer some of these questions.

A central tenet of the Chicago School is that a cartel bears the fruit of its own destruction, because supra-competitive profits attracts new firms. As this reasoning seems plausible, the open question here is why we still observe cartels. How long does it take for entry to destabilize a cartel? More generally, which factors determine the durability of a cartel? Chapter **2** presents a model to address this issue. It is shown that collusion is viable, even when cartel members face the threat of entry. The model allows for a closed-form expression of the expected lifetime of a cartel. Key determinants that affect a cartel's stability are the number of cartel members and the cost of deterring entry.

[1] Robert Bork (1978) is one of the few outspoken critics of antitrust laws. He contends that the American antitrust policy slows down innovation and protects small businesses instead of consumers.

One of the main activities of antitrust authorities is to detect and punish collusive behavior. Given the illegal nature of price conspiracies, firms try to keep their agreements private by negotiating in the proverbial "smoke-filled rooms". The only information that may give away the presence of a cartel is therefore public information such as prices. A high price might indicate the presence of a cartel, but is also consistent with a high-cost industry. An antitrust authority has an *ex post* incentive to investigate the former industry but not the latter. Chapter **3** studies this game between firms and an antitrust authority. The analysis reveals that, when an antitrust authority is unable to commit, firms will collude with some probability. The government can decrease the incidence of collusion by instructing the antitrust authority to maximize consumer welfare instead of social welfare.

Chapter **4** considers semicollusion. When firms engage in semicollusion, they coordinate on some strategic variables, such as the range of products, prices or service provision, but act non-cooperative on others. Even though this form of collusion seems to be ubiquitous, the vast majority of the literature on collusion restricts attention to full collusion. An important open question is how semicollusion differs from full collusion. Does competition on the quality dimension wash away the collusive profits obtained by coordination of prices? Are consumers better off under semicollusion than under full collusion? The analysis in the chapter implies that semicollusion is still profitable for firms, as compared to non-cooperative behavior, but the optimal price depends on the firms' ability to compete through service provision. In particular, when providing service is relatively costly, the cartel chooses to set a high price, knowing that firms will be restricted in competing the collusive profits away. On the other hand, when providing service is relatively easy the cartel chooses to set a low price, as compared to the non-cooperative price, to moderate the degree of competition through service provision. In general, consumers prefer non-cooperative behavior over semicollusion, and semicollusion over full collusion.

Chapter **5** revisits a classic topic of industrial organization: resale price maintenance. The classic Chicago position on vertical restraints such as resale price maintenance is that they are voluntarily agreed to by upstream and downstream firms, and necessarily enhance efficiency. The prevailing view, however, holds that resale price maintenance is pro-collusive and should therefore be banned. Chapter 5 studies a simple model of a manufacturer and two downstream retailers. Under the assumption that the manufacturer and retailers aim to maximize profits, it is shown that resale price maintenance may have an anti-collusive effect. The reason is that by imposing a price floor, the manufacturer makes it impossible for retailers to form a cartel as a high price floor makes it attractive for retailers to deviate from a cartel agreement. This suggests another pro-efficiency interpretation of resale price maintenance.

An important question concerns the interplay between market characteristics and the scope for collusion. It is well-known that certain properties of markets may hinder or foster collusion between firms.[2] For instance, it is easier to collude for firms when consumers order their goods regularly and frequently. There is, however, little systematic knowledge on this relation. Chapter **6** fills this gap by reviewing the existing literature on the ties between collusion and market characteristics for a market that becomes increasingly important: auctions. The bottom line of this chapter is that auctioneers may prevent collusion by twisting and tweaking the auction rules. In response to a cartel, an auctioneer has various tools at his disposal, such as adjusting the auction format, imposing a reserve price, or limiting the bidders discretion in submitting a bid. The task of deterring cartels, therefore, does not rest solely on the shoulders of antitrust authorities.

The discussion on collusion in auctions continues in chapters **7** and **8**. Chapter **7** studies collusion in a multidimensional auction, in which a firm's bid consists of a price and a quality index. The analysis consists of two parts. First, the chapter presents a derivation of the optimal collusive scheme when firms can and cannot make transfers to each other. This exercise helps to understand how cartels work in actual multidimensional auctions. Moreover, the analysis is instrumental in the second part of the chapter, where a number of anti-collusive strategies are discussed. The main insight is that, in order to lower the costs of collusion, auctioneers should not merely announce a minimum quality level and a maximum price, but try to construct a scoring method that ranks price and quality pairs and announce a minimum score below which bids are not eligible. This method is more efficient in the sense that it results in the socially optimal quality level and yields the auctioneer a higher surplus.

Although auctions are a popular method in procurement, an even more frequently used method is to negotiate. This seems puzzling, as auctions are easy to conduct and tend to deliver the buyer better terms of trade than negotiations. Chapter **8** analytically compares the two mechanisms, and find that in some cases negotiations do outperform auctions. Most importantly, a seller is better off negotiating when he is certain that a relatively large bidding ring exists.

[2] See Motta (2004), chapter 4 for a discussion of these factors.

9.2 Avenues for further research

Hopefully, the essays in this thesis provide convincing evidence that collusive behavior forms a rich source of interesting research. There are many ways in which the above models can be extended or modified to yield new insights or applications. This section discusses a few.

The first essay offered a theory of entry deterrence and finite cartel duration. That model is still highly stylized. For instance, entrants are passive bystanders. In practice, entrants do not wait patiently for the incumbents to fail but actively lobby the government as well. A promising extension would therefore be to explicitly model the lobbying process by adding a 'political economy' component in which incumbents, entrants and politicians have a strategic role. Another challenging question is to formulate an econometric model and estimate the expected duration of cartels.

The essay on antitrust enforcement, chapter 3, studied a model in which firms may have two types; low costs or high costs. An obvious extension is to analyze the 'continuous-type' version of the model, in which the costs of firms is drawn from a continuous interval. A related adjustment is to drop the assumption of common costs and consider the case where firms' costs are correlated.

Chapter 4 considered semicollusion. The analysis in that chapter simply assumed semicollusive behavior. It would be interesting to understand why firms adopt this type of collusion instead of full collusion. An answer presumably relies on imposing costs of observing a firm's strategic decisions and assuming that those costs differ across strategic variables. It is arguably easier to observe a competitor's price than its level of service.

The analysis in chapter 5 suggests that it is worthwhile to examine the effect of vertical restraints other than a price floor on the ability to collude. Empirical research is also welcome. Despite the controversial nature of the topic, and the existence of a large theoretical literature, there are few empirical studies of the economic effects of vertical restraints. An empirical study may also provide insights about the empirical relevance of the various theoretical explanations of vertical restraints, including the one proposed in this thesis.

Chapter 6 reviewed the literature on collusion in auctions. The most urgent challenges in this field are empirical: how to detect collusion and how to estimate the welfare costs of collusion? An answer to these questions can probably only be given in the context of a case study, where the researcher has access to detailed (cost) data. An open theoretical issue is to explain the often used practice of organizing a knockout after the actual auction. This method is inefficient and does not seem to maximize a cartel's revenue.

The most promising approach for new research related to chapters 7 and 8 seems to be empirical. There is little empirical research on multi-dimensional auctions. By estimating bid functions for these auctions, economists can potentially estimate the welfare gains or losses of alternative auction formats. Explaining the choice of a mechanism seems to be a highly relevant research topic as well. Insights from such a study could improve auction theory. Understanding the determinants of the choice of a mechanism may also guide public policy. When is it sensible to instruct government agencies to use a particular procurement mechanism? Rich and reliable data are often scarce and an alternative method to study collusive behavior in auctions are experiments.

Of course, there are many other issues left to be explored in antitrust economics. For instance, the profession is now starting to integrate insights from the endogenous growth literature into industrial organization models. In models of endogenous growth (the seminal reference is probably Aghion and Howitt, 1992), firms invest in R&D to become the market leader and render the previous market leader's product obsolete. An important characteristic of endogenous growth models is that firms do not compete 'on' the market, but rather 'for' the market. Segal and Whinston (2007) investigate some implications of this form of competition for antitrust policy. As this literature is still to be developed, there are many interesting open questions. What is, to name just an example, the scope for collusion when firms are involved in a perpetual R&D race? What is the relevance of merger policy in such an environment?

There exists a large body of knowledge on political economics. The majority of articles in that field, however, restricts attention to macroeconomic issues such as monetary policy, income distribution or economic growth, see for instance the textbooks by Drazen (2000) and Persson and Tabellini (2000). Antitrust policy often has a significant political dimension. Governments sometimes encourage a merger of large national firms to create a 'national champion'. And a supra-national or federal antitrust authority, such as the European Commission, may encounter strong local political opposition when it decides to impose a huge fine for price fixing. This political dimension of antitrust is usually ignored in the literature. An exception to this claim are papers by Röller and his co-authors (see Neven and Röller, 2005 or Röller and Waverman, 2001). There are many interesting problems in 'political industrial organization'. How should we view the interaction between politicians and the antitrust authority? In the spirit of the central banking literature, are politically independent antitrust authorities better capable of deterring collusion than dependent ones?

9.3 Policy recommendations

Every essay in this chapter is a theoretical exercise. Yet, one can distill several insights that are relevant for policymakers. Perhaps the most general lesson that can be drawn is that there are many ways to combat cartels. Investigating industries and imposing a fine if a cartel is found is not the only strategy. There are other, more creative, solutions. This section discusses the policy implications in more detail.

The analysis in chapter 2 suggests that the antitrust authority should take the expected duration of a cartel into account when deciding to investigate an industry. The model suggests that industries with a well-organized trade union are more likely to accommodate a long-lived cartel, as are industries which are protected from vigorous competition by an import barrier. Investigation is costly, and should therefore be targeted toward the (potential) cartel with the largest negative impact. A second implication is that policymakers can attempt to decrease the durability of cartels. For instance, the government can lower the import tariffs to induce entry of foreign firms. The strategy of decreasing the durability of cartels can be seen as an indirect way to combat cartels, as compared to the traditional strategy of fining cartels.

The lesson of chapter 3 is that policymakers should carefully rethink the objectives of the antitrust authority. Does the antitrust authority have the right incentives to effectively deter collusion? Related to this issue is the question of how the antitrust authority can be held accountable. In contrast to central banking, where the performance of the central bank can be measured according to an inflation target, there is no obvious, measurable, target in antitrust.

The results in chapter 4 warn antitrust authorities not to take quality, service, or other non-price strategic variables as given when setting a fine for a cartel. Assuming that non-price strategic variables are unchanged under collusion tends to yield biased estimates of the welfare costs of collusion.

The immediate policy implication of chapter 5 is that the current European ban on resale price maintenance should be lifted. The arguments in favor of resale price maintenance, which may be summarized under the header of pro-efficiency, are more compelling than the traditional view that resale price maintenance fosters collusion. The simple model in this chapter demonstrates that resale price maintenance may actually be anti-collusive, which undermines the pro-collusive argument against this vertical restraint.

The U.S. Supreme Court decided in *Leegin* to abolish the illegal treatment of resale price maintenance, and now favors a rule of reason standard.[3] This seems to be an attractive option for the European Union as well. With a rule of reason, the European Union effectively adopts a 'wait-and-see' strategy. When the pro-collusive view turns out to be correct, the Union can still refuse upstream firms to use this restraint.

The articles surveyed in chapter 6 clarify the role of the auctioneer in preventing collusion. By responding to signals for collusive behavior, an auctioneer can adjust the design of the auction to prevent the emergence of a cartel or at least mitigate the negative revenue effects. Thus, collusion can be deterred *ex ante* at the market design stage, instead of *ex post*, by prosecuting an existing cartel.

The most important implication of chapter 7 is that an auctioneer in a multidimensional setting should construct a scoring index to rank multidimensional bids and announce a minimum score below which bids are not eligible. Of course, the construction of such an index can be a difficult exercise, and in some cases prohibitively costly.

[3] *Leegin Creative Leather Products, Inc.* v. *PSKS, Inc.*, 551 U.S. 480 (2007).

Bibliography

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, *60*, 323–351.

Albæk, S., & Lambertini, L. (1998). Collusion in differentiated duopolies revisited. *Economics Letters*, *59*, 305–308.

Albano, G., Buccirossi, P., Spagnolo, G., & Zanza, M. (2006). Preventing collusion in procurement. In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of procurement* (pp. 347–380). Cambridge University Press.

Anderson, S., & Engers, M. (2007). Participation games: Market entry, coordination, and the beautiful blonde. *Journal of Economic Behavior & Organization*, *63*, 120–137.

Anderson, S., & Renault, R. (1999). Pricing, product diversity, and search costs: a Bertrand-Chamberlin-Diamond model. *RAND Journal of Economics*, *30*, 719–735.

Aoyagi, M. (2003). Bid rotation and collusion in repeated auctions. *Journal of Economic Theory*, *112*, 79–105.

Aoyagi, M. (2007). Efficient collusion in repeated auctions with communication. *Journal of Economic Theory*, *134*, 61–92.

Appelbaum, E., & Weber, S. (1992). A note on the free rider problem in oligopoly. *Economics Letters*, *40*, 473–480.

Athey, S., & Bagwell, K. (2001). Optimal collusion with private information. *RAND Journal of Economics*, *32*, 428–465.

Athey, S., Bagwell, K., & Sanchirico, C. (2004). Collusion and price rigidity. *Review of Economic Studies*, *71*, 317–349.

Aubert, C., Rey, P., & Kovacic, W. (2006). The impact of leniency and whistle-blowing programs on cartels. *International Journal of Industrial Organization*, *24*, 1241–1266.

Bagnoli, M., & Bergstrom, T. (2005). Log-concave probability and its applications.

Economic Theory, *26*, 445–469.

Baldwin, L., Marshall, R., & Richard, J.-F. (1997). Bidder collusion at forest service timber sales. *Journal of Political Economy*, *105*, 657–699.

Becker, G. (1968). Crime and punishment: An economic approach. *Journal of Political Economy*, *76*, 169–217.

Besanko, D., & Spulber, D. (1989). Antitrust enforcement under asymmetric information. *Economic Journal*, *99*, 408–425.

Besanko, D., & Spulber, D. (1993). Contested mergers and equilibrium antitrust policy. *Journal of Law, Economics, & Organization*, *9*, 1–29.

Binmore, K., & Klemperer, P. (2002). The biggest auction ever: the sale of the British 3G telecom licenses. *Economic Journal*, *112*, C74–C96.

Block, M., Nold, F., & Sidak, J. (1981). The deterrent effect of antitrust enforcement. *Journal of Political Economy*, *89*, 429–445.

Boone, A., & Mulherin, H. (2007). How are firms sold? *Journal of Finance*, *62*, 847–875.

Bork, R. (1978). *The antitrust paradox: A policy at war with itself*. The Free Press.

Bosch, J.-C., & Eckard, E. (1991). The profitability of price fixing: Evidence from stock market reaction to federal indictments. *Review of Economics and Statistics*, *73*, 309–317.

Brod, A., & Shivakumar, R. (1999). Advantageous semi-collusion. *Journal of Industrial Economics*, *47*, 221–230.

Brusco, S., & Lopomo, G. (2002). Collusion via signalling in simultaneous ascending bid auctions with heterogeneous objects, with and without complementarities. *Review of Economic Studies*, *69*, 407–436.

Bulow, J., & Klemperer, P. (1996). Auctions versus negotiations. *American Economic Review*, *86*, 180–194.

Caillaud, B., & Jéhiel, P. (1998). Collusion in auctions with externalities. *RAND Journal of Economics*, *29*, 680–702.

Carlton, D. (2007). Does antitrust need to be modernized? *Journal of Economic Perspectives*, *21*, 155–176.

Carpineti, L., Piga, G., & Zanza, M. (2006). The variety of procurement practice: Evidence from public procurement. In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of procurement* (pp. 14–44). Cambridge University Press.

Che, Y.-K. (1993). Design competition through multidimensional auctions. *RAND Journal of Economics*, *24*, 668–680.

Che, Y.-K., & Kim, J. (2006). Robustly collusion-proof implementation. *Econometri-*

ca, *74*, 1063–1107.

Connor, J. (2004). Global antitrust prosecution of modern international cartels. *Journal of Industry, Competition and Trade*, *4*, 239–267.

Cooper, J., Froeb, L., O'Brien, D., & Vita, M. (2005). Vertical antitrust policy as a problem of inference. *International Journal of Industrial Organization*, *23*, 639–664.

Cramton, P., & Schwartz, J. (2000). Collusive bidding: Lessons from the FCC spectrum auctions. *Journal of Regulatory Economics*, *17*, 229–252.

Cramton, P., & Schwartz, J. (2002). Collusive bidding in the FCC spectrum auctions. *Contributions to Economic Analysis & Policy*, *1*, Article 11.

d'Aspremont, C., & Jacquemin, A. (1988). Cooperative and noncooperative R&D in duopoly with spillovers. *American Economic Review*, *78*, 1133–1137.

Deltas, G., & Serfes, K. (2002). Semicollusion vs. full collusion: The role of demand uncertainty and product substitutability. *Journal of Economics*, *77*, 111–139.

Dick, A. (1996). When are cartels stable contracts? *Journal of Law and Economics*, *39*, 241–283.

Dimitri, N., Piga, G., & Spagnolo, G. (2006). Introduction. In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of procurement* (pp. 3–13). Cambridge University Press.

Dini, F., Pacini, R., & Valletti, T. (2006). Scoring rules. In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of procurement* (pp. 293–321). Cambridge University Press.

Dixit, A. (1980). The role of investment in entry deterrence. *Economic Journal*, *90*, 95–106.

Drazen, A. (2000). *Political economy in macroeconomics*. Princeton University Press: Princeton, New Jersey.

Dufwenberg, M., Gneezy, U., Goeree, J., & Nagel, R. (2007). Price floors and competition. *Economic Theory*, *33*, 211–224.

Elberfeld, W., & Wolfstetter, E. (1999). A dynamic model of Bertrand competition with entry. *International Journal of Industrial Organization*, *17*, 513–525.

Engelbrecht-Wiggans, R., & Kahn, C. (2005). Low-revenue equilibria in simultaneous ascending-bid auctions. *Management Science*, *51*, 508–518.

Fershtman, C., & Gandal, N. (1994). Disadvantageous semicollusion. *International Journal of Industrial Organization*, *12*, 141–154.

Feuerstein, S. (2005). Collusion in industrial economics–a survey. *Journal of Industry, Competition and Trade*, *5*, 163–198.

Fox, N. (1994). An oligopoly model of ocean liner shipping. *Review of Industrial Organization*, *9*, 343–355.

Friedman, J. (1971). A non-cooperative equilibrium for supergames. *Review of Economic Studies*, *38*, 1–12.

Friedman, J., & Thisse, J. (1993). Partial collusion fosters minimum product differentiation. *RAND Journal of Economics*, *24*, 631–645.

Froeb, L. (1988). *Auctions and antitrust.* (Unpublished, Department of Justice, Antitrust Division)

Fudenberg, D., Levine, D., & Maskin, E. (1994). The folk theorem with imperfect public information. *Econometrica*, *62*, 997–1039.

Genesove, D., & Mullin, W. (2001). Rules, communication, and collusion: Narrative evidence from the Sugar Institute case. *American Economic Review*, *91*, 379–398.

Gilbert, R., & Vives, X. (1986). Entry deterrence and the free rider problem. *Review of Economic Studies*, *53*, 71–83.

Graham, D., & Marshall, R. (1987). Collusive bidder behavior at single-object second-price and English auctions. *Journal of Political Economy*, *95*, 1217–1239.

Green, E., & Porter, R. (1984). Noncooperative collusion under imperfect price information. *Econometrica*, *52*, 87–100.

Grimm, V., Riedel, F., & Wolfstetter, E. (2003). Low price equilibrium in multi-unit auctions: the GSM spectrum auction in Germany. *International Journal of Industrial Organization*, *21*, 1557–1569.

Harberger, A. (1954). Monopoly and resource allocation. *American Economic Review*, *44*, 77–87.

Harrington Jr., J. (2005). Optimal cartel pricing in the presence of an antitrust authority. *International Economic Review*, *46*, 145–169.

Harrington Jr., J. (2007). *Modelling the birth and death of cartels with an application to evaluating antitrust policy.* (Unpublished, Johns Hopkins University)

Heijnen, P. (2007). *Strategic interactions in environmental economics*. Unpublished doctoral dissertation. (University of Groningen)

Hendricks, K., Porter, R., & Tan, G. (2003). *Bidding rings and the winner's curse: The case of federal offshore oil and gas lease auctions.* (NBER Working Paper 9836)

Ippolito, P. (1991). Resale price maintenance: Empirical evidence from litigation. *Journal of Law and Economics*, *34*, 263–294.

Jacquemin, A., Nambu, T., & Dewez, I. (1981). A dynamic analysis of export cartels: The Japanese case. *Economic Journal*, *91*, 685–696.

Jéhiel, P. (1992). Product differentiation and price collusion. *International Journal of*

Industrial Organization, *10*, 633-641.

Jullien, B., & Rey, P. (2007). Resale price maintenance and collusion. *RAND Journal of Economics*, *38*, 983–1001.

Kirkegaard, R. (2006). A short proof of the Bulow-Klemperer auctions vs. negotiations result. *Economic Theory*, *28*, 449–452.

Klemperer, P. (1999). Auction theory: A guide to the literature. *Journal of Economic Surveys*, *13*, 227–286.

Kovacic, W., Marshall, R., Marx, L., & Raiff, M. (2006). Bidding rings and the design of anti-collusive measures for auctions and procurements. In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of procurement* (pp. 381–411). Cambridge University Press.

Kovenock, D., & Roy, S. (2005). Free riding in noncooperative entry deterrence with differentiated products. *Southern Economic Journal*, *72*, 119–137.

Krishna, V. (2002). *Auction theory*. Academic Press.

Landes, W. (1983). Optimal sanctions for antitrust violations. *University of Chicago Law Review*, *50*, 652–678.

Levenstein, M., & Suslow, V. (2006). What determines cartel success? *Journal of Economic Literature*, *44*, 43–95.

Lopomo, G., Marshall, R., & Marx, L. (2005). Inefficiency of collusion at English auctions. *Contributions to Theoretical Economics*, *5*, Article 4.

Mailath, G., & Zemsky, P. (1991). Collusion in second price auctions with heterogeneous bidders. *Games and Economic Behavior*, *3*, 467–486.

Martini, G., & Rovesti, C. (2004). Antitrust policy and price collusion: Public agencies vs. delegation. *Louvain Economic Review*, *70*, 127–151.

Mathewson, F., & Winter, R. (1998). The law and economics of resale price maintenance. *Review of Industrial Organization*, *13*, 57–84.

McAfee, R., & McMillan, J. (1987). Auctions and bidding. *Journal of Economic Literature*, *25*, 699–738.

McAfee, R., & McMillan, J. (1992). Bidding rings. *American Economic Review*, *82*, 579–599.

McAfee, R., McMillan, J., & Reny, P. (1989). Extracting the surplus in the common-value auction. *Econometrica*, *57*, 1451–1459.

McMillan, J. (1991). Dango: Japan's price-fixing conspiracies. *Economics and Politics*, *3*, 201–218.

Milgrom, P. (2000). Putting auction theory to work: The simultaneous ascending auctions. *Journal of Political Economy*, *108*, 245–272.

Milgrom, P., & Weber, R. (1982). A theory of auctions and competitive bidding. *Econometrica*, *50*, 1089–1122.

Motta, M. (2004). *Competition policy. theory and practice.* Cambridge University Press.

Motta, M., & Polo, M. (2003). Leniency programs and cartel prosecution. *International Journal of Industrial Organization*, *21*, 347–379.

Mund, V. (1960). Identical bid prices. *Journal of Political Economy*, *68*, 150–169.

Myerson, R. (1979). Incentive-compatibility and the bargaining problem. *Econometrica*, *47*, 61–73.

Myerson, R. (1981). Optimal auction design. *Mathematics of Operations Research*, *6*, 58–73.

Neven, D., & Röller, L.-H. (2005). Consumer welfare vs. welfare standard in a political economy model of merger control. *International Journal of Industrial Organization*, *23*, 829–848.

Nyborg, K., Rydqvist, K., & Sundaresan, S. (2002). Bidder behavior in multiunit auctions: Evidence from Swedish Treasury auctions. *Journal of Political Economy*, *110*, 394–424.

Orr, D., & MacAvoy, P. (1965). Price strategies to promote cartel stability. *Economica*, *32*, 186–197.

Overstreet, T. (1983). *Resale price maintenance: Economic theories and empirical evidence*. Federal Trade Commission.

Palfrey, T., & Rosenthal, H. (1983). A strategic calculus of voting. *Public Choice*, *41*, 7–53.

Perloff, J., & Salop, S. (1985). Equilibrium with product differentiation. *Review of Economic Studies*, *52*, 107–120.

Persson, T., & Tabellini, G. (2000). *Political economics: Explaining economic policy*. The MIT Press: Cambridge, Massachusetts.

Pesendorfer, M. (2000). A study of collusion in first-price auctions. *Review of Economic Studies*, *67*, 381–411.

Polinsky, A., & Shavell, S. (2000). The economic theory of public enforcement of law. *Journal of Economic Literature*, *38*, 45–76.

Porter, R. (1983). A study of cartel stability: The Joint Executive Committee, 1880-1886. *Bell Journal of Economics*, *14*, 301–314.

Porter, R. (2005). Detecting collusion. *Review of Industrial Organization*, *26*, 147–167.

Porter, R., & Zona, J. (1993). Detection of bid rigging in procurement auctions. *Journal of Political Economy*, *101*, 518–538.

Porter, R., & Zona, J. (1999). Ohio school milk markets: An analysis of bidding. *RAND Journal of Economics*, *30*, 263–288.

Posner, R. (1979). The Chicago school of antitrust analysis. *University of Pennsylvania Law Review*, *127*, 925–948.

Rey, P., & Vergé, T. (2003). Economics of vertical restraints. In *Economics for an imperfect world: Essays in honor of Joseph E. Stiglitz* (pp. 353–390). The MIT Press: Cambridge, Massachusetts.

Rey, P., & Vergé, T. (2008). *Resale price maintenance and horizontal cartel.* (CMPO Working Paper 02/048)

Riley, J., & Samuelson, W. (1981). Optimal auctions. *American Economic Review*, *71*, 381–392.

Robinson, M. S. (1985). Collusion and the choice of auction. *RAND Journal of Economics*, *16*, 141–145.

Rogoff, K. (1985). The optimal degree of commitment to an intermediate monetary target. *Quarterly Journal of Economics*, *100*, 1169–1189.

Röller, L.-H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review*, *91*, 909–923.

Rotemberg, J., & Saloner, G. (1986). A supergame-theoretic model of price wars during booms. *American Economic Review*, *76*, 390–407.

Rothschild, R. (1992). On the sustainability of collusion in differentiated duopolies. *Economics Letters*, *40*, 33–37.

Salmon, T. (2004). Preventing collusion between firms in auctions. In M. Janssen (Ed.), *Auctioning public assets: Analysis and alternatives* (pp. 80–109). Cambridge University Press.

Samuelson, L. (2006). The economics of relationships. In R. Blundell, W. Newey, & T. Persson (Eds.), *Advances in economics and econometrics: Theory and applications, eighth world congress* (Vol. 1, chap. 4). Cambridge University Press.

Segal, I., & Whinston, M. (2007). Antitrust in innovative industries. *American Economic Review*, *97*, 1703–1730.

Shubik, M. (1980). *Market structure and behavior*. Harvard University Press.

Significant B.V. (2005). *Nalevingsmeting aanbesteden 2004. Een onderzoek naar de naleving van de Europese aanbestedingsrichtlijn in Nederland (Compliance check procurement 2004. A study of the compliance of the European guidelines in the Netherlands).* (Report prepared for the Dutch Ministry of Economic Affairs)

Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *RAND Journal of Economics*, *15*, 546–554.

Skrzypacz, A., & Hopenhayn, H. (2004). Tacit collusion in repeated auctions. *Journal of Economic Theory*, *114*, 153–169.

Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. W. Strahan and T. Cadell: Londen.

Spagnolo, G. (2004). *Divide et impera: Optimal leniency programs.* (CEPR Discussion Paper 4840)

Stephan, A. (2006). The bankruptcy wildcard in cartel cases. *Journal of Business Law*, 511–534.

Stigler, G. (1964). A theory of oligopoly. *Journal of Political Economy*, *72*, 44–61.

Stigler, G. (1968). Price and non-price competition. *Journal of Political Economy*, *76*, 149–154.

Stigler, G. (1971). The theory of economic regulation. *Bell Journal of Economics and Management Science*, *2*, 3–21.

Stigler, G. (1977). The conference handbook. *Journal of Political Economy*, *85*, 441–443.

Sun, X.-H. (1996). On a generalization of the Chebyshev inequality. *Acta Mathematica Hungarica*, *72*, 269–281.

Suslow, V. (2005). Cartel contract duration: Empirical evidence from inter-war international cartels. *Industrial and Corporate Change*, *14*, 705–744.

Symeonidis, G. (2002). *The effects of competition. cartel policy and the evolution of strategy and structure in british industry*. The MIT Press, Cambridge, Massachusetts.

Telser, L. (1960). Why should manufacturers want free trade? *Journal of Law and Economics*, *3*, 86–105.

The Vos Committee. (2002). *De bouw uit de schaduw (The construction industry out of the shadows)*. The Hague: Sdu (In Dutch).

Thomas, C. (2005). Using reserve prices to deter collusion in procurement competition. *Journal of Industrial Economics*, *53*, 301–326.

Thompson, J., & Kaserman, D. (2001). After the fall: Stock price movements and the deterrent effect of antitrust enforcement. *Review of Industrial Organization*, *19*, 329–334.

Tirole, J. (1988). *The theory of industrial organization*. The MIT Press: Cambridge, Massachusetts.

U.S. Department of Justice, Antitrust Division. (2008). *Price fixing, bid rigging, and market allocation schemes: What they are and what to look for.*

Vickrey, W. (1961). Counterspeculation, auctions, and competitive sealed tenders.

Journal of Finance, *16*, 8–37.

von Ungern-Sternberg, T. (1988). Cartel stability in sealed bid second-price auctions. *Journal of Industrial Economics*, *36*, 351–358.

Waldman, M. (1987). Noncooperative entry deterrence, uncertainty, and the free rider problem. *Review of Economic Studies*, *54*, 301–310.

Whinston, M. (2006). *Lectures on antitrust economics*. The MIT Press: Cambridge, Massachusetts.

Wilson, R. (1992). Strategic models of entry deterrence. In R. Aumann & S. Hart (Eds.), *Handbook of game theory with economic applications* (Vol. 1, pp. 305–329). North-Holland: Amsterdam.

Wolfram, C. (1998). Strategic bidding in a multiunit auction: An empirical analysis of bids to supply electricity in England and Wales. *RAND Journal of Economics*, *29*, 703–725.

Wolinsky, A. (2005). Procurement via sequential search. *Journal of Political Economy*, *113*, 785–810.

Zimmerman, J., & Connor, J. (2005). *Determinants of cartel duration: A cross-sectional study of modern private international cartels.* (Unpublished, Purdue University)

Samenvatting

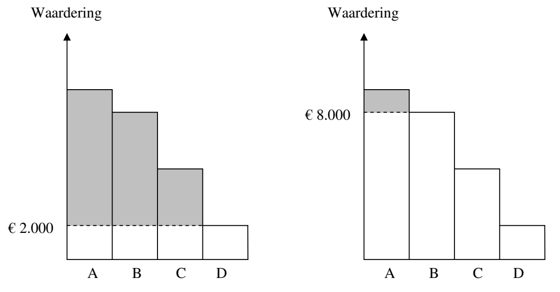
Kort overzicht

Dit proefschrift gaat over de economische theorie van kartels. Er is sprake van een kartel wanneer een aantal bedrijven, expliciet of stilzwijgend, afspreekt om de prijs te verhogen of de kwaliteit te verminderen. In Nederland en veel andere landen is dit verboden, omdat consumenten door dergelijke afspraken meer betalen voor een inferieur produkt. In ieder hoofdstuk probeer ik één of meer aspecten van de dynamiek van kartels beter te begrijpen door een speltheoretisch model op te stellen. Aan de hand van zo'n model kunnen vervolgens methoden worden afgeleid die bijdragen aan het uiteenvallen van kartels of zelfs de vorming ervan voorkomen.

Kartels

Waarom zijn prijsafspraken eigenlijk verboden? Immers, "de concurrent heeft ook vrouw en kinderen". Door het onderling afstemmen van de prijs zijn ondernemers zeker van werk en een goed belegde boterham. Het belangrijkste economische argument voor het kartelverbod is dat prijsafspraken de consument onevenredig hard treffen.

Een voorbeeld. Stel dat op een lokale markt voor paarden vier potentiële kopers zijn; Arnold, Bas, Corine en Daniel. Elke koper heeft interesse in slechts één paard en de bedragen die ze daar maximaal voor willen betalen zijn, respectievelijk, € 10.000, € 8.000, € 5.000 en € 2.000. Op dezelfde markt zijn ook twee paardenfokkers actief. De totale kosten voor het leveren van een paard bedragen, inclusief een redelijke marge voor de aanbieder, € 2.000. In het geval dat de paardenfokkers geen kartel vormen, zullen de kopers het paard kopen bij de aanbieder met de laagste prijs. Dit zal uiteindelijk leiden tot een prijs van € 2.000. Voor Arnold betekent



(a) Concurrentie (b) Kartel

Figure 1. Consumentensurplus op de paardenmarkt.

dit een surplus van € 8.000,want € 10.000-€ 2.000 is € 8.000. Het totale surplus van de kopers (het consumentensurplus) is € 15.000. Figuur 1a vat de situatie samen. Het consumentensurplus is weergegeven als het grijze oppervlak. De winst van de paardenfokkers is precies nul en daarmee is het maatschappelijke surplus (het surplus van consumenten plus de winst van bedrijven) ook € 15.000.

Stel nu dat de fokkers een prijsafspraak maken. Het is voor hen optimaal om € 8.000 per paard te vragen. Andere prijzen leveren minder winst op, zoals eenvoudig is na te rekenen. De winst van de fokkers wordt dan € 12.000, omdat de verkoop aan Arnold en Bas tweemaal € 8.000 oplevert minus de kosten van tweemaal € 2.000. Het consumentensurplus daalt naar € 2.000, zoals is te zien in figuur 1b. Het lagere consumentensurplus hoeft nog geen rechtvaardiging van overheidsingrijpen te zijn. De consumenten zijn weliswaar slechter af, maar de fokkers hebben een hogere winst. En waarom zou de overheid het belang van de fokkers minder zwaar laten wegen dan dat van de paardenkopers?

De reden is dat consumenten onevenredig hard getroffen worden door het kartel. Het verlies van de consumenten weegt niet op tegen de hogere winst. Vóór de oprichting van het kartel was het maatschappelijke surplus € 15.000. Als gevolg van de hogere prijs daalt het maatschappelijke surplus naar € 14.000. Sommige consumenten (in dit geval Corine en Daniel) zijn niet meer bereid te kopen en hun surplus gaat verloren.

Het voorkomen van dit welvaartsverlies is de voornaamste reden om prijsafspraken te bestrijden. Een ander belangrijk argument is dat kartels innovatie en daarmee de economische groei vertragen. Als bedrijven onderling afspraken maken hoeven ze niet meer om de gunst van de consument te strijden door nieuwe of verbeterde produkten aan te bieden.

Bevindingen

Dit proefschrift bestaat uit twee delen. Het eerste deel bevat een viertal essays waarin wordt bestudeerd hoe kartels omgaan met verstoringen van hun marktmacht. Kartels hebben bijvoorbeeld te maken met de dreiging van nieuwe toetreders of toezicht van de mededingingsautoriteit. Kortom, in het eerste deel wordt de invloed onderzocht van dreigingen waar samenspannende bedrijven in de realiteit ook mee geconfronteerd worden. Het tweede deel van het proefschrift gaat in op de werking van kartels bij veilingen.

Deel 1

Het ene kartel is het andere niet. Sommige kartels bestaan tientallen jaren, in andere houden bedrijven het niet langer dan twee jaar met elkaar uit. De negatieve maatschappelijke impact van een kartel is veel groter als het kartel langer bestaat. Het is daarom van belang om te begrijpen wat de determinanten zijn van de verwachte levensduur van een kartel. In hoofdstuk 2 introduceer ik een model om dit te analyseren. De essentie van het model is dat karteldeelnemers moeten investeren om toetreding te voorkomen. De verwachte levensduur van een kartel neemt af als het aantal karteldeelnemers of de investeringskosten toenemen.

Een belangrijke taak van mededingingstoezichthouders is om kartels te voorkomen. Hiervoor spoort de toezichthouder kartels op en deelt een boete uit als een overtreding wordt geconstateerd. Gezien de mogelijk hoge boetes is het niet verwonderlijk dat bedrijven prijsafspraken stil proberen te houden. In het uiterste geval is het enige waarop een toezichthouder zich kan baseren de hoogte van de prijzen. Een hoge prijs kan een indicatie zijn dat een kartel actief is, maar kan ook betekenen dat de kosten hoog liggen. Een toezichthouder zal alleen onderzoek uit willen voeren als er een kartel bestaat. In hoofdstuk 3 bestudeer ik het spel tussen de toezichthouder en bedrijven. Ik laat zien dat bedrijven altijd met positieve kans een kartel vormen. De kans dat dit gebeurt kan worden verkleind door de toezichthouder consumentenwelvaart te laten maximaliseren in plaats van totale welvaart.

In de bestaande literatuur wordt er normaliter van uitgegaan dat karteldeelnemers perfect samenspannen. De praktijk leert dat bedrijven soms prijsafspraken maken, maar tegelijkertijd met elkaar blijven concurreren door bijvoorbeeld meer kwaliteit te bieden. De vraag die ik in hoofdstuk 4 stel is in hoeverre een kartel waarin alleen prijsafspraken maken (een semikartel) verschilt van een kartel waarin ook afspraken over kwaliteit worden gemaakt (een volledig kartel). Hiervoor maak ik gebruik van een model waarin bedrijven zich van elkaar kunnen onderscheiden door een hogere kwaliteit aan te bieden of door toevallig beter te passen bij de persoonlijke voorkeuren van consument. Consumenten zijn niet alwetend en zullen erop uit moeten gaan om te zoeken naar een produkt dat goed bij hen past. Het model kan worden gezien als een wiskundige kijk op de zoektocht van een *shopaholic* naar dat ene perfecte paar schoenen. Net als bij een volledig kartel zijn consumenten slechter af bij een semikartel, hoewel het tweede type minder schadelijk is dan de eerste. Een verrassende uitkomst is dat de prijs bij een semikartel lager kan liggen dan zonder een kartel. Door een lage prijs af te spreken voorkomen de karteldeelnemers dat ze vervolgens een felle concurrentiestrijd om de consument beginnen.

In het vierde essay van dit proefschrift, hoofdstuk 5, bestudeer ik een klassiek onderwerp uit de literatuur: verticale prijsbinding. Dit is een voorwaarde waarbij een fabrikant of groothandelsonderneming een afnemer verplicht om het produkt niet onder een door de fabrikant of groothandelsonderneming vastgestelde prijs te verkopen. Het gebruik van deze voorwaarde stuit vaak op mededingingsrechterlijke bezwaren. Het argument dat hiervoor door de toezichthouder wordt gegeven is dat verticale prijsbinding leidt tot hogere prijzen. In een eenvoudig model laat ik zien dat verticale prijsbinding juist kan leiden tot lagere prijzen, doordat een fabrikant minimumprijzen zal gebruiken om een afnemerskartel te voorkomen.

Deel 2

In hoofdstuk 6 bestudeer ik hoe bedrijven prijsafspraken kunnen maken bij aanbestedingen of veilingen. Het belang van veilingen in de economie is enorm en neemt alleen maar toe. Aanbestedingen zijn helaas vaak zo opgezet dat kartelvorming in de hand wordt gewerkt. Ondernemingen weten, door ervaring of openbare informatie, meestal goed welke andere ondernemingen meedingen naar de opdracht. Daarnaast geeft de aanbestedende dienst vaak openheid over maximale toelaatbare prijs. Het enige wat kartelleden dan nog moeten doen is afspreken wie intekent op deze maximale toelaatbare prijs. Mocht een kartellid het niet eens zijn met deze afspraak en hoger bieden dan de uitverkoren winnaar, dan kunnen de overige kartelleden bij een veiling bij opbod alsnog hoger bieden dan het dwarse kartellid. Afwijken van de afspraak is dan niet winstgevend.

Aan de hand van bestaande literatuur laat ik zien hoe een veiling aangepast kan worden om de kans op een kartel te verkleinen of zelfs uit te sluiten. Dit kan bijvoorbeeld door een reserveringsprijs in te stellen waarboven niet geboden mag worden.

De bestaande literatuur over kartels bij veilingen gaat uit van ééndimensionale competitie: het laagste bod wint. Bij aanbestedingen stelt de opdrachtgever meestal ook eisen aan de kwaliteit. Hoofdstuk 7 breidt daarom de analyse uit naar veilingen waarbij het bod een combinatie is van een prijs en een kwaliteitsaanbod. Ik laat zien hoe de inzichten uit de 'ééndimensionale' literatuur vertaald kunnen worden naar deze situatie. Om de schade van een kartel te beperken kan de opdrachtgever een *reservation utility auction* gebruiken. Dit is een veiling waarbij een bod de opdrachtgever tenminste een minimale prijs-kwaliteit verhouding moet garanderen. In de praktijk wordt vaak een maximumprijs en een minimumkwaliteit ingesteld. De *reservation utility auction* levert de opdrachtgever meer op dan een combinatie van een maximumprijs en een minimumkwaliteit.

Er bestaan natuurlijk meer methoden dan veilingen om een produkt te kopen of verkopen. Een veel gebruikte methode is om te onderhandelen. In hoofdstuk 8 vergelijk ik veilingen met onderhandelingen. Het blijkt dat onderhandelingen de verkoper meer opleveren dan een veiling als de kopers een kartel hebben gevormd.